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SECONDARY IMPACTS OF INFRASTRUCTURE INVESTMENTS IN THE DENVER REGION

Environmental Impact Center, Incorporated

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Statistical correlations between the amount and form of land use changes and the location of new highways and wastewater facilities were established for four major metropolitan areas individually and in combination. The statistical findings were supplemented with results from a dynamic simulation model of land use in metropolitan Washington. The broader study [Secondary Effects of Public Investments in Highways and Sewers] emphasizes approximations which helped generalize results across different metropolitan areas. This report presents econometric analyses derived for the Denver region. These statistical analyses illustrate the historical influence of highways, water, and sewer facilities in shaping land use patterns in the Denver area and provide basic methods for forecasting impacts of future investments.

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PREFACE

This report presents empirical findings describing the influence on land use of public investments in highways, water supply, and wastewater facilities in the Denver metropolitan area. Historical investments in these facilities were related to changing land use patterns for the period 1960-1970. The results provide quantitative measures of secondary impacts of such investments on urban development.

Our findings are structured in the form of four equations relating ten-year land use changes to existing social and economic conditions and to public investments. This structure has the practical value of allowing intermediate-term projections of secondary impacts in each of some 180 districts in the Denver region. Land use projections are subdivided into four categories: single-family housing, multi-family housing, commercial land, and industrial land.

The equations are highly simplified characterizations of urban development. They represent historical rather than current or future relationships. As a result, they should not be used indiscriminately, nor should their projections be accepted as point projections of future impacts. In particular, we wish to discourage policy or investment decisions based solely on application of these or similar equations.

Application of these equations should provide a valuable input when used in conjunction with other information. Most important are the opinions and analyses of planners and officials experienced and knowledgeable in local affairs. Since the present study did not include all possible factors influencing land use, it is necessary that local planners identify specific conditions that might modify or substantially alter historical projections.

A second crucial item of information is the current status and historical efficacy of land use plans and controls. Historical projections contain no explicit representation of land use controls, yet the changes they describe are in many cases dependent on the permission of local authorities. Hence, present or anticipated land use plans and controls may have a major impact on forecasts of secondary impacts.

The above caveats are intended to reinforce an awareness that historical projections are inherently imprecise. Even where the caveats do not apply, forecasts are subject to error. But while there is no magic in forecast numbers, a fair degree of confidence can be placed in the direction and magnitude of both the land use changes and secondary effects estimated. This is a first step in developing practical techniques for identifying, and to some extent quantifying, secondary impacts. We hope they will provide useful new inputs to public decision-making in the Denver region.

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I. INTRODUCTION

Secondary impacts of investments in land based transportation and wastewater collection and treatment play an important role in urban development. The potential magnitude of their effect may be gauged from the magnitude of current federal investment in these facilities -- over ten billion dollars annually.

The National Environmental Policy Act (NEPA) of 1969, and similar Acts by some fifteen states, require government agencies to prepare, in advance, environmental impact statements for all major actions. According to the Council on Environmental Quality, which assists in administering NEPA, "many major federal actions, in particular those that involve the construction or licensing of infrastructure investments...stimulate or induce secondary effects in the form of associated investments and changed patterns of social and economic activities. Such secondary effects, through their impacts on existing community facilities and activities, may be even more substantial than the primary effects of the original action itself."

The secondary effects discussed in this report are long term changes in land use brought about by major investments. A central problem in identifying and forecasting secondary impacts is attribution -- the determination of what part, if any, of urban growth can be ascribed to public investments. There are many instances where new houses, offices, shops, and industries seemingly sprouted overnight next to a highway or major road. There is an intuitive feeling that this phenomenon is one of cause and effect -- that the highway in some fashion brought about new development.

Is this intuitive judgement correct? Does it extend to other public investments? Answers to these questions are elusive. However, some answers can be provided by identifying economic and social activities affected by public investments and assessing this influence relative to other forces that shape urban growth.

The treatment of secondary impacts in current environmental statements is often vague. This deficiency is caused primarily by a lack of assessment techniques rather than a lack of appreciation of the possible importance of such impacts. The techniques developed here are based on a comprehensive review of the literature and on case studies in four metropolitan areas. Consistent patterns of impacts and combinations of local conditions that produce them were identified from the literature. Case studies in the Boston, Denver, Minneapolis-St. Paul, and Washington metropolitan areas were used to establish quantitative relations which may be used in projecting likely secondary impacts of investments in public facilities.

The empirical studies were based on econometric analyses. Statistical correlations between the amount and form of land use changes and the location of new highways and wastewater facilities were established for each area individually and for the four major metropolitan areas in combination. The statistical findings were supplemented with results from a dynamic simulation model of land use in metropolitan Washington.

While the broader study emphasized approximations which helped generalize results across different metropolitan areas, this report presents econometric analyses specifically derived for the Denver region. These statistical analyses illustrate the historical influence of highways, water, and sewer facilities in shaping land use patterns in the Denver area and provide basic methods for forecasting impacts of future investments.

II. SECONDARY IMPACTS AND THEIR CAUSES

A. Secondary Impacts

Secondary impacts are economic, social, and land use changes that occur over time as an indirect result of construction, operation, and use of public facilities. They may include changes in business activity, employment, personal and public finances; changes in population levels and effects on community stability and cohesion; and altered land use patterns reflecting economic and social impacts.

The importance of secondary impacts derives, at least in part, from the fact that they accumulate with time. Their geographic scale may range from the nation as a whole to an individual parcel of land. The most significant secondary impacts, however, are manifested by intra-metropolitan changes. To the extent that secondary impacts involve investments in new structures and facilities -- new houses, office buildings, factories -- they may be considered permanent rather than transient events.

Research on secondary effects of highways has been conducted during the last forty years. Techniques have been developed for categorizing, measuring, and, to some extent, forecasting secondary impacts of highways. Investments in mass transit and wastewater facilities have received less attention in this respect. However, available research suggests that although the ways in which these three forms of public investment influence development differ, the kinds of changes they cause are similar.

B. Kinds of Secondary Impacts

Secondary impacts are commonly classified in broad categories based on economic change, social and demographic change, and land use change. Within each category, many variables or indicators can be used to measure specific impacts.

Economic secondary effects have received by far the most attention. Changes in employment, sales, number of businesses, capital investment, and in land and property values are common measures of economic impacts.

Social and demographic effects include changes in population size and characteristics, and other, more subtle, changes in social interaction among individuals and groups. Population characteristics that may change include age structure, income and skill levels, and racial and ethnic mix. A substantial amount of research has been done on relatively abstract social impacts, for example, on community cohesion and stability, on neighborhood linkages, and on community values.

Land use changes are, in a sense, derivatives of economic and social impacts, since both of these imply some change in the use of land. A general measure of land use impacts is the conversion of vacant land to residential, commercial, and industrial uses.

A common framework is essential for integrating these different measures of secondary effects into a meaningful picture of the impact of a project. The fact that economic and demographic impacts are reflected in land use changes provides a means for establishing such a framework. The measure of secondary impacts of public investments used in this study is change in land use.

C. Mechanisms of Impact

Public investments induce secondary effects principally through their influence on locational decisions of individuals and groups. Transportation and wastewater investments influence location decisions largely through their immediate effect on the attractiveness of areas they serve for various kinds of development. The specific mechanisms through which they exert this influence depend on the investment.

1. Transportation

Transportation facilities have an immediate effect on travel times between locations in an area. They also usually reduce the danger and expense of traveling, and in general, make it easier to get from place to place. The concept commonly used to represent these changes and their relation to location decisions is "accessibility."

Accessibility is a characteristic of locations. It expresses the ease of travel from a given place to desired destinations. Accessibility, therefore, depends not only on transportation facilities and levels of service, but also on the existing spatial distribution of activities and destinations. Changes in accessibility introduced by new transportation investments -- and ultimately the secondary effects associated with them -- depend upon existing levels of transportation service and existing land use patterns.

Individuals and groups have different needs for travel. Accordingly, accessibility is often subdivided by type of destination, e.g., access to households, to employment, etc. According to most research, the dominant travel requirement of households is the "journey to work," i.e., access to employment. This is understandable, since work trips are made twice daily and are absolutely essential to the well being of the household. Other travel, such as to shopping or to amenities, is of lesser importance.

There is no single dominant transportation requirement for businesses. Rather, there are four general needs which vary in importance for different kinds of businesses: access to materials, customers, labor, and services. Some business groups, such as extractive industries, are restricted to locations near raw material sources. Others may be virtually restricted because of the costs of transporting bulky or heavy materials. Most industries, however, seek locations where access to materials, labor, customers, and services are all satisfactory.

Manufacturing industries serving national markets tend to regard access to a labor pool as the most important need in choosing a specific site. Service and trade industries, which require direct access to consumers, regard proximity to local markets as most important.

The needs of households and businesses are obviously interdependent. To businesses, households represent both a labor pool and a market for their goods or services. To households, businesses are sources of employment as well as places to shop or be entertained.

Although any major transportation investment increases accessibility within a region, it may sometimes have an opposite effect on individual communities and neighborhoods. Multi-lane, limited access highways and, to a lesser extent, surface rail mass transit lines, may act as physical barriers dividing communities or neighborhoods into separate components. Physical isolation of a portion of a community can disrupt or weaken the social stability of the area.

2. Wastewater Facilities

The role of public investments in wastewater facilities, such as sewers and treatment plants, is not as well-defined in location decisions as that of transportation facilities. Sewers are less pervasive than roads and are not always necessary; septic tanks, for example, are often an alternative. However, with growing concern over water quality, public wastewater systems have begun to play an increasingly important role in the urban development process.

Less is known about secondary impacts of wastewater investments than those of transportation facilities. It appears that secondary impacts of new sewers occur primarily through an increase in the potential density of development. Since sewer lines provide substantial capacities for removing and disposing of water wastes, they allow intense development in the locations they serve. More units per acre of land imply reduced land costs per unit. In many cases, increased building density may make the difference between a profitable development and a money-losing project.

Sewer service may be provided through either public or private investment. Private service is possible for large residential developments where economies of scale reduce marginal costs per unit to an acceptable level. Private wastewater disposal is also often found for large commercial units and for industrial development. These observations imply that lack of public sewers does not necessarily constrain development, but may limit it to specific types. On the other hand, availability of public sewer service may stimulate all forms of development.

Industries that require substantial amounts of water are a special case. Such industries traditionally disposed of their wastes in nearby streams or rivers, usually with little or no treatment. The 1972 Federal Water Pollution Control Act Amendments, however, aim at a zero discharge policy by 1985. Accordingly, some industries which historically have disposed of their own water wastes may become increasingly sensitive to the availability and location of public sewer service.

Transportation and wastewater investments interact in influencing development: areas with high accessibility and public sewer service are more attractive than areas with only one of these features. Transportation and wastewater investment decisions are themselves interdependent. Urban growth following transportation investments creates new demand for public wastewater service, and *vice versa*.

These interactions are part of the overall urban development process. The impact of public investments thus depends on the relative importance of the availability of public services within the overall set of factors that shape urban growth.

D. A General Approach to Secondary Impacts

A comprehensive economic analysis of urban growth requires extensive formulation of utility functions, supply and demand curves, and market clearing processes. While significant progress has been made in specifying such relations, the overall models are too complex for practical application. However, given the limited objective of examining secondary impacts of public investments, economic analysis can be restricted to the production of new structures.

A large majority of new structures is produced by professional developers. Developers are the principal agents of change of urban land use patterns, since they actually make the decisions to construct structures in specific locations. Therefore, a direct, though simplified, approach is to assess the likely response of professional developers to new public investments in infrastructure facilities.

Like all producers of economic goods, developers attempt to maximize profits. Structure types are matched to available sites in order to yield profitable development. Market prices of alternative sites depend on locational characteristics including accessibility and sewer service. Production costs vary with type of structure and with locational characteristics such as topography, availability of sewer service, local government requirements, etc. The most attractive sites for developers are those in which production costs are low relative to market price. In any one location, the relation of cost to price may vary for different types of structure.

While developers take into account preferences of potential customers, they have no direct interest in building on sites most desirable to customers, i.e., in optimizing the preferences of households and businesses. Developers, therefore, make the initial trade-off between preferred characteristics and price. They attempt to anticipate the premium that households and businesses will pay for increased accessibility, public services, attractive neighborhoods, etc., and compare it with marginal increases in construction and land costs to determine potential profits. If profits are acceptable, construction occurs. Their decisions are later reflected in the housing stock and commercial or industrial space from which households and businesses select particular structures.

The basic approach described here, namely estimates of the response of professional developers to investments in public facilities, was used to develop the quantitative models described in Chapter III and in Appendix A. Projections of secondary effects using this general framework are limited to land use changes arising through new urban development.

III. ESTIMATES OF SECONDARY IMPACTS IN THE DENVER REGION

A. Introduction

Estimates of secondary impacts are inherently uncertain. Social and economic responses to public investments depend on a multitude of human decisions. Although we may justifiably assume that most of these are based on objective criteria, and hence are to some extent predictable, judgements of individuals and communities are bound to differ. Accordingly, any forecast of secondary impacts is at best probable; it is never certain.

The approach described here for estimating secondary impacts of public investments in the Denver region was developed from an examination of the recent history of the metropolitan area. It is evident that any analysis based on the past -- even the very recent past -- may be in error when applied to the future. Attitudes, opinions, and preferences may change. Again, therefore, estimates of secondary impacts must be looked upon merely as probable future events.

Finally, the estimates are based on statistical analyses. As we know, the validity of a relation cannot be judged simply from its statistical significance, nor can the reliability of a causal model be judged merely from how well it explains statistical results. Statistical relations should "make sense" before they are accepted. The procedures developed here are based on probable cause-effect relations discussed in Chapter II. The data and statistical analyses used to arrive at quantitative relationships are described in Appendix A. The detailed assumptions and results given there should be examined in the light of the particulars of specific applications; use of these results should be based on an assessment of how reasonable the postulated relations are for the area being considered.

The procedures described below yield estimates of the influence of public investments on land conversion as well as estimates of expected overall land conversion. Together, these forecasts can be used to assess the significance of infrastructure investments in terms of new development expected in the district.

The importance of potential secondary effects depends to a large extent on local conditions. Generally speaking, secondary impacts may be considered significant if there is conversion of large amounts of undeveloped or agricultural land to urban use or if there is substantial change in the character of an existing community. A large amount of induced development is clearly important by itself. However, even a small amount of development may be important if it changes the character of a community. For example, if a highway stimulates construction of apartment complexes in a low-density, single-family residential area, the impact may be important even though the number of new structures is small.

The procedures presented give ten-year projections of secondary impacts. Longer term forecasts are not appropriate using simple analytic techniques since they tend to be inaccurate. Thus, when we speak of potential impacts, we refer in all cases to estimates of ten-year changes.

Secondary impacts are estimated on a district-by-district basis. The EMPIRIC model* calibration districts have been used for the statistical analyses. These districts are, on average, about 3,500 acres in size. However, the outlying portions of the Denver metropolitan area were divided into districts substantially larger than the average. If geographically more detailed projections are required in such areas, these districts may be subdivided into smaller units without violating the assumptions of the techniques. Districts smaller than about 2,000 acres introduce additional uncertainty in forecasts and should be avoided.

B. Changes in Land Use

The procedures described below yield estimates of the influence of public investments on land conversion and on expected overall land use. Together, these forecasts can be used to assess the significance of secondary impacts in terms of new development in each district.

Regression equations project amount of development, classified into four types, over a ten-year period. Projections are based on data for a base year and on planned investments in public facilities during the forecast interval. The coefficients for the equations shown in the Tables were estimated using 1960 as the base year and the period 1960-1970 as the forecast interval.

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* Peat, Marwick, Mitchell and Company, EMPIRIC Activity Allocation Model: Application to the Denver Region, prepared for the Denver Regional Council of Governments, December 1972.

C. The Regression Equations

Equations represent each of four types of land conversion:

- Single-family residential (dwelling units/acre)
- Multi-family residential (dwelling units)
- Commercial (acres)
- Industrial (acres)

The explanatory variables (independent variables) include:

- Base year distance from the center of the district to the nearest major highway (miles)
- Change in distance to the nearest highway (i.e., distance in base year less distance in forecast year)(miles)
- Vacant land within the district (acres)
- Base year sewered vacant land plus change in sewered vacant land (acres)
- Base year watered vacant land plus change in watered vacant land (acres)
- Base year total residential vacancy rate (i.e., total dwelling units less total households divided by total dwelling units times 100)(percent)
- 1/total land in district (1/acres)

Precise definitions of each variable are given in Appendix A. In the single-family housing equation, estimates of multi-family and industrial development are used as explanatory variables, reflecting competition for land between low density residential and higher intensity uses. Similarly, the estimate for single-family construction is included in the commercial equation to represent the desire of commercial developers to locate near new markets. Because of this interaction among dependent variables, estimates of land use changes must be made in sequence. Industrial and multi-family projections are made first since these results are required for single-family forecasts; these last, in turn, are used to make projections of commercial land conversion.

D. Industrial Land Conversion

Equation 1 provides estimates of conversion of land to industrial use. The equation has the form:

Total Industrial Acres in Forecast Year = b_1 (Industrial Acres in Base Year)

+ b_2(Base Year Distance to Highway) + b_3(Change in Distance to Highway)

+ b_4(Watered Vacant Land) + b_5(Vacant Land) + b_6(1/total land) + constant

The coefficients b_1-b_6 and the constants are given in Table 1. Standard errors, t statistics, and the R^2 and F values indicate the level of uncertainty for each coefficient and for the expression as a whole. To illustrate its application, consider a typical district in the Denver region.

The characteristics of the district in the base year were:

Acres of industrial land in the base year	100 acres
Base year distance to nearest highway	2.7 miles
Base year plus change in watered vacant land	1,300 acres
Base year total vacant land	2,150 acres
Land in district	3,500 acres

A proposed new highway is to be constructed 1.4 miles from the center of the district; thus, the change in distance to nearest highway is 1.3 miles. The potential secondary effect of this highway on industrial land use in the district is estimated by solving the equation

Table 1

Estimates of Land Conversion to Industrial Use[1]

Equation 1.

Total Industrial Acres in Forecast Year =

b_1(base year industrial acres) + b_2(base year distance to highway)

+ b_3(change in highway distance) + b_4(base year + change in watered vacant land)

+ b_5(total vacant land) + b_6(1/total land) + constant

Coefficient	b_1	b_2	b_3	b_4	b_5	b_6	Constant
Estimated Value	1.07	-13.1	14.4	0.016	-0.001	-12.0×10^3	37.2
Standard Error	±0.015	±3.59	±4.08	±0.002	±0.001	$\pm 5.5 \times 10^3$	
T-statistic[2]	69.38	-3.65	3.52	6.13	-0.65	-2.25	

Coefficient of Determination (R^2) = 0.97

F-Value[3] = 1.01

---

[1] See Section III for definition of variables.

[2] T-statistics at the 1%, 5%, and 10% levels are 2.326, 1.645, and 1.282, respectively.

[3] The F-value at the 1% confidence level is approximately 2.8.

with and without the change in distance resulting from the proposed investment.

With the highway, the estimate of forecast year industrial acres is 143 acres, or a change of 43 acres. Without the highway, estimates are 124 acres in the forecast year, a change of 24 acres. Thus, 19 acres of industrial land conversion may be associated with the new highway. This estimate can also be obtained directly by multiplying the coefficient of the change in highway distance (1.3 miles) by b_3 in equation 1. The result is (1.3 miles)(14.4 acres/mile change) or 19 acres.

A measure of the secondary effects of the highway is the proportion of expected industrial land conversion that may be associated with the improvement in highway service. In this instance, this amounts to (19/43)(100) or about 44%. Another measure is the proportion of future year stock which may be associated with the proposed highway service improvements. This amounts to (19/143)(100) or about 13%. Thus, the secondary impacts of the highway service improvements are substantial when measured against expected changes in land conversion in the district; they are, of course, much more modest when expressed in terms of total amount of industrial land in the forecast year.

E. Multi-Family Housing Units

Table 2 shows the regression equation for estimating multi-family housing construction. Highway investments do not enter significantly in this expression. However, sewer investments are important.

Consider the effect of a proposed sewer line in a district with the characteristics given in the previous example. Additional data include:

Table 2

Estimates of Multi-Family Housing Units(1)

Equation 2.

Total Multi-Family Units in Forecast Year =

b_1(base year multi-family units) + b_2(sewered vacant land) + b_3(sewered vacant land)^2

+ b_4(vacant land) + b_5(residential vacancy rate) + constant

Coefficient	b_1	b_2	b_3	b_4	b_5	Constant
Estimated Value	1.13	0.16	-0.22×10^{-4}	-0.006	-48.9	461
Standard Error	±0.04	±0.09	$\pm0.17\times10^{-4}$	±0.01	±13.7	
T-statistic(2)	25.31	1.72	-1.32	-0.451	-3.58	

Coefficient of Determination (R^2) = 0.81

F-Value(3) = 125

---

(1) See Section III for definitions of variables.

(2) T-statistics at the 1%, 5%, and 10% levels are 2.326, 1.645, and 1.282, respectively.

(3) F-value at the 1% level is approximately 2.8.

Number of multi-family housing units in the base year	425 units
Base year sewered vacant land	300 acres
Proposed increase in sewered vacant land	500 acres
Base year residential vacancy rate	6.7 percent

The proposed sewer will add 500 acres to the existing 300 acres of sewered vacant land. From equation 2 without the proposed sewer, we estimate a total of about 647 multi-family units in the forecast year, or an increase of 222 units. With the sewer, the estimate is about 715 units in the forecast year or an increase of 290 units. The difference of 68 units is attributable to the proposed sewer. The secondary impact of improved sewer service, therefore, is about (68/290) or about 23% of construction. Alternatively, we may say that about (68/715)(100) or about 10% of the forecast year stock of multi-family units may be considered to be associated with the improvement in sewer service.

F. Single-Family Housing Units

Projections of forecast year single-family housing units are based, in part, on the preceding estimates of industrial land conversion and multi-family housing construction. The single-family equation is shown in Table 3.

The land-related variables are normalized by dividing by district size. For a typical district in Denver, the normalized values for base year conditions are:

Single-family dwelling units	1.23 units/acre

Table 3

Estimates of Single-Family Housing Construction[1]

Equation 3.

Total Single-Family Units in Forecast Year/Acre =

b_1(base year single-family units/total land) + b_2(change in highway distance)

+ b_3(base year + change in sewered vacant land/total land)

+ b_4(base year + change in watered vacant land/total land) + b_5(vacant land/total land)

+ b_6(residential vacancy rate) + b_7(industrial land conversion/total land)

+ b_8(multi-family units constructed/total land) + constant

Coefficient	b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8	Constant
Estimated Value	0.89	0.03	0.74	0.19	0.07	-0.034	-2.0	-0.04	0.14
Standard Error	±0.03	±0.01	±0.16	±0.16	±0.14	±0.93	±0.93	±0.02	
T-statistic[2]	27.03	1.72	4.53	1.19	0.50	-3.66	-2.17	-1.92	

Coefficient of Determination (R^2) = 0.91

F-Value[3] = 227

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(1) See Section III for definition of variables.
(2) T-statistics at the 1%, 5%, and 10% levels are 2.326, 1.645, and 1.282, respectively.
(3) The F-value at the 1% confidence level is approximately 2.8.

Base year plus change in sewered vacant land	.27 acres/acre
Base year plus change in watered vacant land	.34 acres/acre
Total vacant land	.38 acres/acre
Industrial land conversion (1960–1970)	.01 acres/acre
Multi-family housing construction (1960–1970)	.20 units/acre

The value for change in distance to highway remains unchanged. For this sample district (size = 3,500 acres), the highway service improvement accounts for a 49% of single-family housing construction. However, in terms of forecast year stock, increases in single-family construction associated with the highway service improvement amount to only 3% of the total stock.

G. Commercial Land Conversion

Table 4 presents a regression equation for commercial land conversion. Impacts of sewer investments are calculated in the same fashion as the example for multi-family housing. Highway investments, however, do not affect commercial land use directly in this equation, as indicated by the absence of the change in distance to highway variable. Instead, new highways affect commercial land conversion indirectly, through their influence on single-family housing. The single-family housing construction variable in equation 4 can be used to calculate this effect.

As an example, we can return to the highway investment discussed previously, which causes a 1.3 mile change in distance from the center of the district to the nearest highway. Single-family construction

Table 4

Estimates of Land Conversion to Commercial Use(1)

Equation 4.

Total Commercial Acres in Forecast Year =

b_1(base year commercial acres) + b_2(base year distance to highway)

+ b_3(base year + change in sewered vacant land)

+ b_4(base year + change in sewered vacant land)^2 + b_5(single-family units constructed(*))

+ b_6(1/total land) + constant

Coefficient	b_1	b_2	b_3	b_4	b_5	b_6	Constant
Estimated Value	1.05	-1.46	0.002	-4.2×10^{-7}	0.01	7.9×10^{3}	7.9
Standard Error	± 0.06	± 0.37	± 0.001	$\pm 2.6 \times 10^{-7}$	± 0.002	-	± 3.2
T-statistic(2)	16.45	-3.91	1.42	-2.10	4.60	-	2.43

Coefficient of Determination (R^2) = 0.75

F-Value(3) = 85.2

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(1) See Section III for definition of variables.
(2) T-statistics at the 1%, 5%, and 10% levels are 2.326, 1.645, and 1.282, respectively.
(3) The F-value at the 1% confidence level is approximately 2.8.
(*) Estimated from Equation 3.

without the highway is estimated (using equation 3) to be .04 dwelling units/acre. With the highway, this estimate is .08 dwelling units/acre. Since the sample district contains 3,500 acres, these estimates convert to 140 and 280 new dwelling units. To calculate the effect of the highway on commercial development, these alternative values for single-family construction should be used to solve equation 4. In this example there were 17 acres of commercial land in the base year.

The difference between these two solutions is the impact of the highway on commercial land use. In this case it amounts to some 13 percent of conversion of commercial land and 5 percent of forecast year stock.

H. Empirical Problems in Estimating Impacts

Two major empirical problems must be addressed in actual application of the expressions suggested here for estimating impacts: selection of districts for analysis and collection of relevant data. As noted above, EMPIRIC districts for the Denver area are the most appropriate subdivisions for estimating impacts. However, districts can be chosen on the basis of a proposed project and/or the scope of the evaluation to be made. If secondary effects of a proposed facility throughout the region are to be evaluated, then relatively large districts are appropriate. If, on the other hand, the evaluation is to be limited to a single jurisdiction or small portion of a metropolitan region, then it may be appropriate to subdivide this small area into a number of districts for detailed examination of impacts.

It is important to note, however, that very large or very small districts cannot be treated reliably by the expressions given here.

Districts smaller than about 2,000 acres were not effectively represented in the regression analyses and should be avoided in applying these equations.

Municipal boundaries often represent natural subdivisions for defining districts. Municipalities usually are of an appropriate size, and reflect internally consistent land use patterns. However, where municipal areas are outside the district size limits suggested here, they should be aggregated or subdivided appropriately.

Data sources and their geographic base have a practical bearing in selecting analysis districts. District boundaries must often be tailored to match data sources. For residential data (single- and multi-family dwelling units, vacancy rates), the Census of Housing provides a convenient source. The other explanatory variables, however, require collection of local data.

Data for land-related variables -- commercial and industrial land, sewered vacant land, and total vacant land -- are typically difficult to obtain. In the past few years, however, many local jurisdictions and metropolitan planning agencies have compiled land use data files which are regularly updated. Such files are probably the best source of information. The Denver Regional Council of Governments has been active in constructing and maintaining data files for the metropolitan area. If particular data are not available, local sources such as zoning maps and files, or property tax rolls may be consulted.

Data on sewered vacant land may be obtained from local or regional sewer authorities. Here again the Council of Governments is a central source of information. Maps of sewer line placements and legal service areas are available and relevant data on service areas in each district may be obtained from the maps. The amount of converted land (residential, commercial, industrial, and intensive institutional) within each district can then be subtracted from service area to obtain estimates of sewered vacant land. This approach assumes that all converted land within each district is sewered. Where this is not a good assumption, estimates have to be adjusted by multiplying by an appropriate ratio for each district.

To the above estimates for sewered vacant land in the base year are added land areas to be served by proposed sewer facilities. Legal service areas for new sewers can be obtained from local authorities. Where data are lacking, a one-mile band on both sides of a proposed new sewer can be used for the service area. Already converted land may then be subtracted from total land in the service area to yield a value for newly sewered, vacant land.

Base year and change in distance to highway are easily calculable from local maps. Once analysis districts have been defined, a highway map can be used to measure relevant distances to the center of each district.

Collection of data on commercial and industrial development presents special problems. There is no simple structural measure similar to residential dwelling units for use in evaluating commercial and industrial development. Although floor space is frequently used as an indicator of supply in construction professions, it has major drawbacks for our purposes. Areas used for parking, equipment and machinery, outdoor processing, etc., are not included in floor space estimates.

Therefore, the amount of land actually devoted to industrial and commercial use bears no consistent relationship to floor space. In addition, data on floor space are not available for many areas.

Commercial and industrial land use is measured in terms of acres rather than a structural variable for this analysis. This measure allows inclusion of the extraneous uses mentioned above. Relevant data may be obtained from land use studies, zoning maps, or tax files.

Precise definitions of the kinds of activities that fall into commercial and industrial categories are provided in Appendix A. There were some errors and inconsistencies in commercial and industrial data, a problem also likely to occur in applying these expressions. Forecasts for commercial and industrial land conversion are therefore less precise than for residential construction. However, in spite of random measurement errors, forecasts of land use changes should remain statistically unbiased.

When data from various sources are combined, different dates of collection may make it impossible to select a base year for the forecasts consistent with all sources. Inconsistencies of as much as two years may be tolerated. Differences of this size or smaller should not bias the results under normal circumstances.

Instances in which only an incomplete set of data is available may arise. It is likely that problems will be encountered in obtaining data for some variables or for some districts. In the absence of precise data, rough estimates are almost always possible. Where such estimates are used, forecasts should be assessed with caution.

Accuracy of data has, of course, a substantial influence on the reliability of forecasts. Accordingly, care should be exercised in collecting and checking data so that an internally consistent set is obtained. However, it may be useful to note again that forecasts are inherently imprecise, even when the data are precise. Forecasts of secondary development are potential, rather than necessary, future events in an impacted area. Accordingly, the judgement of local planners and of other knowledgeable officials should be sought in evaluating forecasts for each district.

To provide examples of the use and accuracy of the equations, four "historical" applications to actual districts in the Denver region are presented in Appendix B. Data on 1960 conditions and public investments from 1960-1970 were used to estimate 1960-1970 construction. These estimates of development are compared to actual events during the period, and measures of impacts of historical highway and sewer investments are provided. Appendix C presents a complete listing of relevant data for the EMPIRIC model calibration districts in 1970.

APPENDIX A

DERIVATION OF THE REGRESSION EQUATIONS FOR THE DENVER REGION

The regression equations presented in Chapter III are based on econometric analyses with data for the Denver metropolitan area. These statistical tests were intended to serve two purposes: determination of the historical influence of highway and sewer facilities in shaping Denver regional land use patterns, and development of methods for estimating impacts of proposed future investments.

Empirical research on the Denver region was part of a larger study of secondary effects. Findings of the project as a whole are documented in "Secondary Impacts of Infrastructure Investments," Final Report, submitted to the Council on Environmental Quality by EIC, Inc., December 1974. Results reported here are supplemental analyses for the Denver region alone.

A. Summary Review of Previous Relevant Research

1. Highways

A general conclusion of previous studies is that highways have little influence on single-family, low-density residential land use (1-3). Retrospective case studies typically have found no significant correlations between single-family housing construction and distance to new highways or changes in accessibility, although some exceptions are evident (4). On the other hand, studies of residential preferences (e.g., Reference 5) provide clear evidence that households are strongly influenced in their residential location decisions by accessibility, i.e., the length of the journey to work. However, such studies also show that higher-income workers -- the principal consumers of single-family housing -- are less sensitive to access. In terms of housing production, the response of professional developers to new highways cannot be gauged by the preferences of consumers, since developers need only satisfy some, but not all, consumer preferences.

Definite highway effects on multi-family residential construction have been established, but their quantitative extent is unclear. Several studies document apartment construction at urban highway interchanges (6-8), particularly interchanges of circumferential highways. The actual probability that any specific interchange will be so developed remains uncertain, as does the distance from the interchange to which this influence extends.

There is general agreement that new highways stimulate commercial development, particularly near interchanges (9,10). Several studies also suggest that new urban highways have a negative impact on downtown trade (11,12) by helping to shift trade to suburban locations.

Studies of highway effects on industrial land use are internally inconsistent. Many attitude and preference surveys suggest that industries desire sites in close proximity or with good access to highways (13-15). Statistical analyses of actual industrial location in relation to highways do not support the survey results (16). Obviously, this preference must be counter-balanced by other factors, for example, land costs. It seems clear that a principal cause of industrial suburbanization was availability of inexpensive land (relative to the CBD) for new plants (17). However, the shift would have been impossible without good access to suburban labor markets provided by highways.

To summarize, the available evidence suggests that households and businesses prefer good access to a highway, all other factors held constant. In terms of actual location, single-family housing construction has a tenuous connection to new highways; multi-family residential and commercial development appear to be influenced by highways; and the relation of industrial development to highways is unclear.

2. Wastewater Facilities

Empirical evidence on the influence of wastewater investments on development is limited and unclear. We may note, for example, that in the various versions of EMPIRIC (18), the influence of sewer service is inconsistent across household and employment categories. In the original Boston EMPIRIC, sewered land weighted by vacant land was positively correlated with most categories of employment change; no similar correlations were found in Washington. However, the nature of the dependent variables, i.e., district changes in shares of households (by income and by employment type), and the step-wise estimation procedures used may have obscured actual correlations between sewer service and land use.

Rogers (19) found that availability of public sewer service was a significant explanatory variable for conversion of vacant and agricultural land to urban uses. It was also observed (19) that while the influence of other factors showed lags of from three to six years, sewer service availability did not. The sewer variable, however, was less influential than measures of accessibility to employment and elementary schools.

Milgram (20) found a strong correlation between (vacant) land price and public sewer service. Prices of land parcels within service areas of trunk sewers were, on average, four times higher than for parcels without sewer service. Multiple regression analyses showed that sewer service, together with allowable developmental density (defined by zoning), were the two most influential determinants of land price.

Kaiser (21) incorporated sewer service in an index of public utilities as one explanatory variable of residential subdivision development within urban areas. However, the public utilities index was much less important than a socioeconomic index reflecting various structural and demographic characteristics of neighborhoods.

The weight of evidence suggests that public sewer service is a significant factor in urban development. However, its precise importance is unclear. Part of the difficulty is caused by the fact that there is no clear cut way of defining levels of sewer service.

Most of the studies cited used a binary dummy variable for sewer service, reflecting either its presence or absence from parcels of vacant land. In evaluating the overall effects of wastewater investments rather than development of individual land parcels, it seems preferable to examine the influence of a sewer facility by the size of its service area, i.e., the amount of land in which service is available.

Few studies have attempted to ascertain the influence of sewers on different forms of land use. The EMPIRIC results for distribution of households are inconclusive; other studies (19-21) focused almost exclusively on low density single-family residential land use. Intuitively, it seems that higher density land uses should be more sensitive to the availability of public sewer service, since they require some form of group collection and disposal system.

A reasonable inference from previous work is that extensions of public sewer service stimulate residential development and that intensive multi-family and commercial uses are particularly sensitive to sewer service. A relation, if any, of industrial development to public sewers has not been established.

B. A General Approach to Secondary Effects

1. Influence of Access and Sewer Service in Urban Development

A comprehensive economic analysis of urban growth requires extensive formulation of utility functions, supply and demand curves, and market clearing processes. While significant progress has been made in specifying these relationships, the resulting mathematical models are so complex as to limit their usefulness in practical application (22). However, our interest is limited to the influence of public investments on urban growth. Within this relatively narrow perspective, economic analysis can be restricted to the actions of developers as producers of new structures.

Such a simplification has several appealing features. Although urban growth derives from the interdependent activities of households, businesses, and government officials, developers make the original decisions about where and what to build. A focus on their decisions reduces the necessary analysis to one group rather than several. While households and businesses may consider countless factors -- subjective as well as objective -- in making location decisions, a developer considers the few most important objective factors, since he has a limited amount of time and no motivation to evaluate individual, subjective criteria. Finally, the developer has a clearly defined motivation -- profit -- whereas households or businesses may have other immediate interests in making locational choices.

Developers are concerned with satisfying the needs and preferences of their customers while maximizing their own profits. The customers, households and businesses, desire sites that are accessible, have adequate public services, and have attractive socioeconomic features. Their preference for structural characteristics is not included in this analysis, since developers build a standardized mix rather than tailor construction to individual desires.

Because consumers have overlapping preferences, they compete for sites, driving up land prices in locations with a combination of attractive features. Developers attempt to estimate the premium households or businesses will pay for attractive sites and compare it with costs of constructing various types of structures on each site. The result of this comparison determines whether development will occur in a particular location and the form it will take.

The influence of public investments is reflected in altered attractiveness and subsequent price adjustments. Increased accessibility and higher potential density of development affect attractiveness and hence price. Since price responses are imperfect, a new highway or sewer may increase attractiveness while land costs remain unaffected for some time. In fact, anticipation of investments may allow developers to buy land at lower prices than warranted by the increased attractiveness of the location after the investment is constructed.

A single unattractive feature of a location can effectively discourage development in spite of several other attractive characteristics. Depressed residential portions of central cities, for example, often have high accessibility and relatively low land prices. Private redevelopment seldom takes place because of the unattractive socioeconomic character of such locations.

2. Factors Influencing Secondary Effects

(a). Land Availability and Price. Availability of land and raw land prices are central factors in developer decisions about where and what to build. Price and availability are usually inversely correlated. Higher prices generally require more intensive development. Hence communities with large amounts of available land at low prices are most attractive to single-family housing developers, while those with little available land, high land prices, or -- in the typical case -- both, can only be developed at higher densities.

Several combinations of conditions involving land availability and price create a strong possibility for important secondary impacts following a transportation investment. If large amounts of undeveloped land are available at a relatively low price, any increase in accessibility will have significant impacts. Modest increases in access levels may stimulate single-family development. Large increases in accessibility may encourage intensive development as well -- multi-family housing, industrial, and commercial. After a large increase in access, condominiums, two-family houses, and apartment developments are likely, with high rise apartments and business offices occurring in "pockets" of high accessibility such as highway interchanges or near transit stations. If, on the other hand, only small amounts of land are available and existing prices are high, modest accessibility increases will have no major impacts, while large increases may stimulate high density construction.

Land availability and price play a similar role in determining the impact of sewer investments. Here the important factor is how much undeveloped land is in the service area of the new sewer, and the related range of prices. Large amounts of vacant land at low prices signify a potential for single-family housing construction. Higher prices and/or lesser amounts of undeveloped land make multi-family residential, industrial, and commercial development more likely.

Because highways traverse and serve many communities with different combinations of land availability and price, they may cause a full range of secondary impacts. Radial highways in metropolitan areas, for example, may stimulate single-family housing construction in outlying areas with low land prices and extensive undeveloped land, mixed single-family and higher density construction in partially developed suburban communities, and high-intensity commercial, industrial and residential construction in the fully-developed inlying suburbs. The last impact, however, is atypical; central areas are much more likely to lose population and business activities after highways because of migration to the suburbs.

(b). Land Use Controls. Zoning and other forms of local land use control are intended to protect existing residents from discordant forms of development. They limit the use and intensity to which individual parcels of land may be put. In theory, therefore, they influence the amount of development of each kind that can occur in a community and potentially limit secondary effects.

The simple fact is that local land use plans are seldom effective unless they are made in conjunction with a long range master plan and are rigorously enforced. This combination is the exception rather than the rule. In most communities or counties, variances are so easy to obtain that zoning provides almost no control of land use. Thus, even where comprehensive land use plans exist, pressures to rezone counter to planned uses often renders them ineffectual.

In evaluating the likelihood of secondary impacts in a community, the most significant features of its land use controls are the existing amounts of undeveloped land zoned for each category of use and the historical record of how thoroughly zoning has been enforced. If variances have been difficult to obtain, then developmental impacts probably will be restricted to levels near the amount of properly zoned vacant land for each category of use. The most common implication of this situation is a limitation on the amounts of industrial, commercial, and multi-family residential development that can occur, with little or no limitation on single-family housing construction. However, if variances are easy to gain, then zoning will have no moderating or controlling influence on impacts; land availability and price, access, and sewer service will determine the form and amount of development that occurs.

(c). Income Level of Existing Residents. There is some evidence that, with all other factors held constant, developers prefer to build single-family housing in areas where the existing population have higher than average income levels. This influence is caused by the preferences of families who desire detached single-family homes for attractive socioeconomic features. They desire the "right" kind of neighbors, as well as attractive structural characteristics implied by upper income levels. This influence is not a dominant one, but it suggests that where a new highway or sewer line serves communities similar in most respects but varying in income levels, the upper income communities will receive more single-family construction than low or middle income areas. The relationship does not hold for other forms of development.

Communities with very high average income, on the other hand, are likely to be exclusive with regard to multi-family housing, or large commercial and industrial development. The exclusion may also extend to relatively dense single-family housing -- two or more units per acre. Such exclusive practices, usually reflected in land use controls or policies, serves to constrain new development and, therefore, secondary effects. Very high income ranges, therefore, can signify that important secondary effects are unlikely in spite of land availability, substantial increases in accessibility, or new sewer investments.

(d). Existing Levels of Access and Sewer Service. The availability of transportation and public sewer facilities and existing levels of service in a community or area strongly affect the probability for major secondary impacts following a new investment. Increases in accessibility beyond a certain point, or extension of sewer service in locations where substantial amounts of sewered land are already available, have only a marginal effect on the attractiveness of the area for development. It is large and dramatic shifts in accessibility or sewered vacant land that create the potential for significant secondary effects. In metropolitan areas with an existing and extensive network of highways, further investments will, on the whole, have a modest influence on development. However, this does not imply that no important secondary effects will occur; almost always, a few portions of the region will experience major increases in access. But the extent of significant impacts will be highly localized, rather than widespread.

The importance of existing accessibility levels is more complex than that of sewered available land. Since access changes are ultimately reflected in land prices, developers of low density structures, e.g., single-family housing, must build where accessibility is relatively low, while the higher intensity developers can afford locations with high access. Therefore, in some intermediate range, higher accessibility causes an area to become decreasingly attractive to low density developers and, at the same time, increasingly attractive to higher intensity developers. If a predominantly single-family community with moderate accessibility experiences a large increase in access, the ultimate effect, as land prices adjust, will be to discourage single-family housing construction. Such an impact, of course, would depend on the other conditions in the community -- land availability and existing price, zoning, etc. On the other hand, extensions of sewer service area or increased sewer or treatment plant capacities do not discourage any form of development; their positive influence is, however, smaller where already existing levels of service are adequate.

(e). Vacancy Rates. Residential, commercial, and industrial vacancy rates are indices of local market conditions to developers. High vacancy rates serve as indications of lack of demand for existing structures at current price levels. At any particular time, of course, some structures will be vacant as transactions take place. This "frictional" vacancy rate can range as high as several percent. Rates above this level imply slack markets, while lower rates suggest market tightness.

Highways and accessibility changes alter demand levels and may thus tighten the market and reduce vacancy rates. We would expect, however, that new construction would occur only after existing stocks of structures had proved insufficient to meet demand, unless the structures themselves were outdated. Therefore, short term secondary effects of highways should be less substantial when vacancy rates are high.

Wastewater investments are somewhat different in that they affect the production side rather than the demand side of urban development. Therefore, in spite of reduced costs, developers may have little incentives to build in areas with high vacancy rates because of the absence of demand. New sewer facilities in such instances should have minimal secondary effects.

The combination of vacancy rates and land availability provides perhaps the best simple measure of developmental potential in an area.

Vacancy rates are indicative of development pressure. Land availability indicates what kind of development is likely: large amounts of vacant land imply a potential for low intensity (e.g., detached homes) construction, while small amounts suggest that dense development will occur. It is possible, of course, to identify some situations where these general rules do not hold, for example, overcrowded areas in central cities. These two indicators are, however, adequate for most areas outside the urban core.

3. Interactions Between Factors

We have discussed above some factors which determine the likelihood for secondary effects in an area. Although we have treated these separately, it is the combination of such factors in a community that determines whether new investments will significantly affect development there. In many areas, these factors are related to each other in such a fashion that certain combinations of conditions are much more likely than others. For example, high levels of accessibility usually reflect concentrations of activities and, therefore, small amounts of vacant land, as well as high land costs. Conversely, low accessibility generally indicates dispersed activities, substantial amounts of undeveloped land, and low prices. There is an implicit progression in these relationships, from large tracts of undeveloped unsewered land, low prices, and low access to fully developed and sewered, high priced, very accessible areas. The former are characteristic of the urban-rural fringe and the latter of mature urban communities. Transportation and wastewater investments cause secondary impacts by creating combinations of conditions that hasten this progression.

Individual communities and towns are interdependent within any given metropolitan area in the sense that households, businesses, and developers evaluate the characteristics of each town relative to other communities in the region. Conditions in a single community, therefore, have no absolute importance alone, but rather are important relative to conditions in other parts of the area. Each community is an element of the larger system. This relativistic character makes it difficult to associate amounts of development with specific values for land price, accessibility, land availability, and other characteristics.

Interactions have been ignored in the quantitative analysis that follows. Clearly, the quantitative results are only approximations justified by their relative simplicity as against a dynamic model which would capture interactions between variables and changes with time. Simplicity was necessary since local officials generally do not have adequate resources for an extensive analysis of potential secondary impacts.

C. Development of Quantitative Relations

1. Mathematical Specification

As the first step of empirical analysis, the hypotheses concerning local land markets, developer responses, and the mechanisms through which public facilities exert their influence were structured in the form of a simple mathematical model. A system of four simultaneous equations was specified, comprising the factors influencing developer decisions and secondary effects.

The underlying model is one in which households and businesses have demands for particular kinds of structures in particular geographic zones. These demands are matched with existing supplies of structures through a market mechanism in which prices adjust so as to ration supply and allocate it to the highest bidder. As demands increase, prices are bid up and these in turn provide signals to developers to increase the supply of particular kinds of structures in particular zones. Given the expected prices at which different kinds of structures will be sold, the developer makes decisions on the basis of expected profitability. Expected prices generate the revenue side of the profit equation, while costs of alternative kinds of development are determined by land costs, planning costs, and construction costs.

While it would be desirable to model this mechanism explicitly, the crucial variable, price of each type of structure in each zone, is not available from published data sources. Therefore, a reduced-form version excluding price variables was specified:

$$\Delta P = f(\Delta H, H, Z_c, R, V, S, \Delta S, W, \Delta W, t) \qquad (1)$$

$$\Delta C = g(\Delta P, K, L, Z_n, X, S, W) \qquad (2)$$

$$K = h(r, X, W, S, S_1) \qquad (3)$$

$$L = k(H, W, S, X, t) \qquad (4)$$

where for each structure type in each local market area:

ΔP = change in expected selling price
H = highway service measure
ΔH = change in highway service
Z_c = socioeconomic characteristics
R = regional growth rates
V = vacancy rate
S = sewer service
ΔS = change in sewer service
W = water service
ΔW = change in water service
ΔC = construction (number of units)
K = costs of construction per unit structure

L = land costs
X = number of acres of undeveloped land
Z_n = zoning index
S_1 = soil characteristics
t = local tax rate
r = interest rate (cost of capital)

Each variable carries implicit time and location subscripts. The change variables, indicated by Δ's, occur over some pre-specified time interval; all other variables represent conditions in the base year of that interval.

Equations 1, 3, and 4 can be substituted into 2 leaving a single vector equation (reduced form) to be estimated:

$$\Delta C = f(\Delta H, H, Z_c, R, V, W, \Delta W, S, \Delta S, t, r, X, S_1) \qquad (5)$$

Several important simplifications have been made to derive this structure and reduced form. The most drastic is for equation (1). Rather than modeling property demand and supply functions for the entire stock of structures and positing particular mechanisms for market clearing and price adjustment, it is assumed that changes in variables that increase demand have an upward pressure on prices. Developers take cognizance of changes and projections of factors affecting demand and form expectations of price movements in the absence of substantial change in the stock of structures. Highway service, neighborhood (zone) characteristics, wastewater service, and tax rates are all assumed to affect the price that users would pay for structures of certain sorts in particular zones. Regional growth rates of particular user classes (population and business) are assumed to affect the expected increase in demand pressures, while vacancy rates suggest how much additional demand can be accommodated without eliciting price increases. Highway service and changes in highway service are reflections of actual transport systems, actual and expected congestion on various segments, and expected additions to the system.

The only other equation in which highway service enters, (4), indicates that improved accessibility will increase land prices, and this in turn, through (2) will affect the rate of construction adversely. In fact, the role of land prices and demand factors in (2) is purposefully ambiguous. If markets for land were perfectly competitive and all actors had equal access to information, the price of land should capture all excess profits that would be associated with developing it for its most profitable use. That is, if developers were to acquire land at competitively determined prices, the profitability of developing any parcel of land in the metropolitan area would be equal, reflecting the cost of capital, for the most profitable use of the land. In such a world, equation (4) would be redundant. In fact, we know that the world does not provide equal information to all parties. The possibilities of "sharp" developers being spurred to develop properties that they are able to buy cheaply from naive owners are real. If firms are not perfect profit maximizers, high land prices will force them to consider high density developments that they might otherwise not consider.

The actual quantities of construction that take place are determined by equation (2). The assumption is that construction levels will vary directly with levels of profitability. Expected price increases will stimulate construction, while high construction and land costs will dampen the supply response to increased demand. Zoning and wastewater services can facilitate or retard implementation of otherwise profitable development. While there is room to argue that zoning and sewerage decisions are accommodative to developmental pressures, we considered them to be exogenously-determined variables that impinge on the developer's decision. Finally, availability of large tracts of undeveloped land makes the problem of land assembly simpler and should be an important variable explaining the quantity of development that takes place.

When the substitutions are made into (5), it is obvious that the coefficients of each of the independent variables in (1)-(4) are not recoverable. Rather, the coefficients estimated for (5) will be combinations of the various coefficients from the basic equations. For instance, the coefficient associated with highway service will embody both the demand factors of (1), the land-price effects from (4), and indirectly, the effect of land price on construction from (2). However, as argued earlier, the principal effects of transportation investments on development come through the highway access-induced premium that will be paid by demanders of structures.

In contrast, the sewer and water service variables enter each of the equations. It is to be anticipated, however, that their effect on demand will be minimal, while their influence on construction costs will be significant.

The reduced form (equation 5) served as the basic model in subsequent statistical analyses. Further simplifications were made because of problems with lack of data on tax rates, soil conditions, and zoning. Interest rates were omitted since they are generally uniform within a metropolitan area. In later stages of the research, additional variables were introduced to try and represent explicitly competition for land among consuming groups. These changes are documented in subsequent portions of this section.

Because of the simplified nature of the regression specifications and the combination of several parameters from the structural system of equations into single coefficients for estimation, it was difficult to make inferences from statistical results concerning the adequacy or validity of the original equations. Since we were interested in single-equation models rather than a recursive simultaneous equation system, no attempt at such inferences was made. The structural form was used principally as a guide for early specifications.

2. Definition of Variables

Multiple regression analyses were used to estimate versions of the above reduced form with data from the Denver region. The region was cross-sectionally subdivided into 182 districts, each of which represented a unit of observation for the regressions. Values for 1960 represented base year conditions in each district, while 1960-1970 changes were used for the dependent (construction) and policy (public investment) variables.

Four dependent variables were used in most regressions: single-family housing construction, multi-family housing construction, commercial and industrial land conversion. The basic set of explanatory variables included four measures of public investments and two measures of local market conditions. Two forms of highway service variable were used: accessibility and proximity to highways. The full set of variables is defined in detail below.

(a). Dependent Variables.

(1). Number of single-family dwelling units in the district. The definition of a housing unit is that of the 1970 Housing Census, User's Guide, Part I, p. 113, U.S. Department of Commerce, October 1970. Data were obtained from Table H-1, "Occupancy and Structural Characteristics of Housing Units." Single-family homes comprise structures with one unit.

(2). Number of multi-family dwelling units in the district. The same Census tables were used and all structures with more than one housing unit were included.

(3). Number of acres of commercial land in the district. Primary data (EMPIRIC) came from areal photographs in each city, with the following kinds of land use classified as commercial:

a. Hotels, motels, tourist homes or tourist camps

b. Retail establishments, including: food, supermarket, drug store, hardware

c. Mixed retail, services, and residential (either 1-story mixed retail and services, or 2-story building with 2nd floor residential)

d. Eating and drinking places

e. General retail and dry goods (clothing, apparel, accessories department store, furniture, appliances)(retail)

f. Lumber, building materials, feed (retail)

g. Gasoline service stations

h. Automotive dealer, farm and heavy equipment, marine equipment, trailer sales (retail)

i. Personal services: barber-beauty shops, cleaning and dyeing, collection, shoe-shine

j. Office buildings -- business services, dental services, electronics (research and development), legal and professional services, medical services, offices and office buildings not classified elsewhere (does not include transportation, communication, and utilities), repair services (except automotive repair), wholesale services (without stocks)

k. Finance, insurance, real estate services -- banking services, savings and loan offices, finance and insurance corporation services, insurance and real estate brokers services

l. Vacant office buildings

m. Hospital -- including clinic, institutional home, nursing home, old people's home, rest home, orphanage

n. Indoor recreation, entertainment -- including athletic club, gymnasium, bowling alley, clubs, lodges, fraternities, sororities, indoor swimming pool, skating rink, indoor theater, movie house, night club, YMCA, YWCA

o. Cultural, religious -- including art gallery, museum, assembly hall

(4). Number of acres of industrial land in the district. The following categories of land were included in the industrial category:

Durable Manufacturing:

a. Furniture, lumber, other durable goods -- manufacturing

b. Metals and allied fabricating -- manufacturing

c. Machinery, transportation equipment -- manufacturing (except electrical machinery)

d. Scientific and professional instruments, electrical machinery -- manufacturing

Non-Durable Manufacturing:

e. Food, allied products -- manufacturing

f. Textiles, apparel, allied products -- manufacturing

g. Chemicals, petroleum, plastics, rubber, allied products -- manufacturing

h. Paper, allied products -- manufacturing

i. Printing, allied industries

j. Leather, leather products -- manufacturing

k. Vacant manufacturing building -- all types of manufacturing

Non-Manufacturing:

l. Bus, taxi -- motor passengers terminal, depot, garage

m. Truck transportation

n. Dock, port facilities

o. Vacant transportation, communications, public utility building

p. Intensive wholesale, storage (enclosed) -- allied products, appliance, automotive, dry goods, electrical, food, hardware

q. Extensive wholesale, storage (open yards) -- auto salvage, building materials, chemicals, lumber, petroleum (gas-oil), wrecking yard

r. Vacant wholesale, warehouse, storage building

Extensive Industrial:

s. Railroad facilities -- depot, repair shop, yards

t. Airport facilities (non-military)

u. Mine, quarry, sand and gravel pit

v. Utilities, communications -- electric, gas, sanitary services, plant sub-station, valve station, power line, gas line, row, radio, tv antenna, telegraph-telephone facilities

(b). Explanatory Variables.

(1). Base year distance (in miles) to the nearest major highway. Measurements were made on maps of each region. All limited access, divided highways were included. Some ambiguities were encountered where highways changed from limited to free access or from divided to undivided within the region. In such cases we did not include stretches that were undivided or free access. For definition of highway types, see: Highway Research Board, "Highway Capacity Manual," Special Report 87, Division of Engineering and Industrial Research, Washington, National Academy of Sciences-National Research Council, 1965.

(2). Change in distance (1960-1970) (in miles) to the nearest major highway. The same definitions and procedures were used.

(3). Sewered vacant land. Public sewer service was measured by vacant, sewered land (in acres) in each district. Vacant land is defined in (5) below. Originally, base year sewered vacant land and change (1960-1970) in sewered vacant land were included as separate variables. There was, however, a high degree of correlation between the two; accordingly, they were combined into a single sewer service variable.

(4). Watered Vacant land. Public water service, a crucial factor in the water-short Rocky Mountain area, was measured by the amount of vacant land in the service area of water lines in each district. As was the case for sewer service, base year watered, vacant land and change (1960-1970) in watered, vacant land were summed to form a single variable.

(5). Vacant, developable land (in acres) in the district. Privately owned agricultural land, vacant lots, forest land and woodlands, are considered vacant developable land. Undevelopable land is land that is swamp or has excessive slope (greater than 15%) or has some other clear impediment to development.

(6). The total residential vacancy rate in the district. The vacancy rate was defined as the ratio of total housing units less total households divided by total housing units.

3. Problems with Sewer and Water Service Measures

The definitions of base year sewered vacant land and change (1960-1970) in sewered vacant land in a district are easy to formulate but difficult to apply with data usually available. For each district, the definitions are:

(base year sewered vacant land)

= (vacant land in sewer service area)

= (land in sewer service area) - (developed land in sewer service area)

(change in sewered vacant land)

= (1970 sewered vacant land) - (base year sewered vacant land)

The first difficulty in using these definitions is the precise delineation of sewer service area. Usually "legal" service areas are proscribed for sewers within which new hookups may be authorized. Unfortunately, these boundaries tend to expand as developmental pressure increases. An alternative measure of the service area of interceptor sewers is the area physically bounded by drainage patterns and topography. An interceptor sewer typically serves a definite catchment area. However, this measure tends to overstate effective service area, since portions of the drainage basin are usually too distant to allow hookups without substantial further investments in collector sewers. Furthermore, the drainage-defined sewer area may be expanded at any time by construction of pumping stations and force mains to transport wastewater between watersheds.

For the Denver region, data on legal service areas were not available. We used the EMPIRIC service area measures, which assume that interceptor and trunk sewers serve an area extending one mile on both sides of the sewer lines. This is a crude measure, but is more likely to reflect effective service area than topographic boundaries.

Similar problems arose in measuring watered vacant land. In this case, however, topographic service areas do not exist, since water is provided under pressure and service can be easily extended across catchment boundaries. One mile bands on both sides of water lines were also used to estimate water service areas.

With service area thus defined, the total land in the service area within a given district is easily obtained. However, developed land within the service area is not known. What is available for each district is total developed land. The assumption was made that all developed land in the base year was within the service areas of existing sewers and water lines. With this assumption, base year sewered and watered vacant land are given by total land in sewer service area less total developed land in the district. This procedure doubtless introduced error, since some fraction of developed land within a district was probably unsewered. However, as we point out below, this error is counterbalanced to some extent by the approximations made in estimating changes in sewered and watered vacant land.

Changes in sewered and watered vacant land are estimated by calculating newly served land using, as above, the service area for the new lines (i.e., a one-mile band on both sides of each line) and subtracting base year, served vacant land. Since in the final specification, variables consisting of base year plus change in sewered and watered vacant land were used, these combined variables can be obtained by calculating total land in the service area for all sewers and water lines in the district and subtracting total developed land within the district. An appropriate correction is made for land that is not developable.(Parks, other public lands, and extensive commercial and industrial land were excluded. No correction was made for swamp or highly sloped land, since sewer service usually is not extended to such areas.)

4. Sample Characteristics

Mean district and total regional values for the dependent and independent variables are shown in Table A.1.

D. Regression Analyses

In addition to quantifying the specified relationships, our regression analyses were used to help resolve several remaining issues. Most important were: normalization of the equations, non-linearities in relationships, and representation of competition for land among consuming groups.

The question of normalizing the equations arose because the districts composing the Denver study region vary widely in size. In this situation, larger districts might inherently tend to receive more construction, without regard to the factors embodied in the equations. If this were the case, then the equations should be normalized to correct for variations in development caused by district size. In addition to the issue of theoretical adequacy, there was the pragmatic problem that any influence of zone size could bias or reduce the efficiency of statistical estimates.

To address this problem, two formulations were tested initially, one normalized for district size, and the other unnormalized. We then compared residuals from the alternative regressions to check for any bias from zone size. Results are documented below.

The issue of non-linearities in relationships is common to statistical analyses. While very few relationships in the social sciences are linear, the difficulties associated with determining the shapes of non-linear curves usually prove insurmountable. Seldom is any theoretical or a priori guidance available as to what forms relationships may take. While we might plausibly expect all of our explanatory variables to exert non-constant influence on development, it was not feasible to carry out a detailed series of tests for alternative functional forms and parametric relationships. On the other hand, we felt that the potential non-linearities in our land-related variables -- sewered vacant, watered vacant, and total vacant land -- were important. It seemed quite likely, for example, that the availability of these stocks would be influential only within a certain range of amounts, beyond which further increases would not affect construction activities.

To test these assumptions, we used polynomial expressions for the sewer, water, and vacant land variables in an alternative series of regressions. The polynomial form implies that these variables have a parabolic relationship with the dependent variables. However, we anticipated that the maxima of the parabolas would occur at the higher range of values for the land-related variables, thus implying that negative effects (signified by a negative slope for the parabola) did not occur in the data.

Table A.1

Sample Characteristics

Number of Districts (N) = 182; Mean District Size = 3,530 acres.

	Development per District			
	Mean 1960	Mean 1970	Mean Change	% Change
Single-Family Dwelling Units	1220	1515	295	24.2
Multi-Family Dwelling Units	430	685	255	59.3
Commercial Land (acres)	17	30	13	76.5
Industrial Land (acres)	100	133	33	33.0
	Regional Totals			
Single-Family Dwelling Units	222,000	276,000	54,000	24.3
Multi-Family Dwelling Units	78,000	125,000	47,000	60.3
Commercial Land (acres)	3,100	5,500	2,400	77.4
Industrial Land (acres)	20,200	27,700	7,500	37.1

	Local Conditions (per district)	
	Mean per District	Standard Deviation
Base Year Distance to Highway (1960)	2.7	2.3
Change in Distance to Highway	1.2	1.8
Base Year + Change of Sewered Vacant Land	794	1110
Total Vacant Land (1960)	2151	4169
Residential Vacancy Rate* (1960)	6.7	3.6

* This value is the mean of vacancy rates for each district. Average values for the area as a whole were 5.8% in 1960 and 4.2% in 1970.

Figures A.1 and A.2 show the theoretically hypothesized and expected parabolic relationships between sewered vacant land and multifamily construction as an example. In the former, the influence (slope) of sewered vacant land gradually diminishes to zero. In the latter, the same curve occurs up to the point of zero influence, but beyond that point the parabola continues with negative slope. We anticipated, however, that this region of the parabola would be an extrapolation from our data by the regression, rather than an estimate from actual data points. The simple polynomial specification, therefore, should reflect the diminishing marginal influence of each land-related factor as is theoretically hypothesized.

The final issue, representation of competition for land among consuming groups, results from the highly simplified structural form used in specifying equations. Initially, no explicit treatment of competition was included, because this phenomenon is dynamic, and therefore beyond the scope of essentially static equations. In addition, the size of subregional districts used clearly determines to a large extent whether competition effects will show up in regressions. In large districts, there may be ample land to accommodate competing forms of development. Even if competition were occurring within such districts, our data would reflect the opposite, namely, co-location of supposedly competing groups.

The Denver regional data, however, comprised primarily small (i.e., a few square miles) districts, so that inclusion of competition factors in the equations seemed feasible. Preliminary regressions confirmed that such factors were important in Denver,* and the supplemental analyses presented here include tests of competition effects in addition to the variables in the reduced form.

The following pages describe the development of the basic four equation model of land use change. Results are subdivided by construction type. A similar series of tests was made for each. Initial specifications included normalized and un-normalized forms, with both linear and polynomial land variables. Subsequently, unimportant or inadequate variables were omitted, and statistical corrections for bias were made where necessary.

1. Single-Family Housing Construction

Tables A.2 - A.4 present initial regression results for single-family housing construction. The tables show, respectively, an unnormalized, linear formulation; an unnormalized, polynomial specification; and a normalized, polynomial specification.

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* Interestingly, Denver was the only region for which competition factors were consistent in their effects. The other regional data sets contained districts averaging twice the size of Denver's or larger.

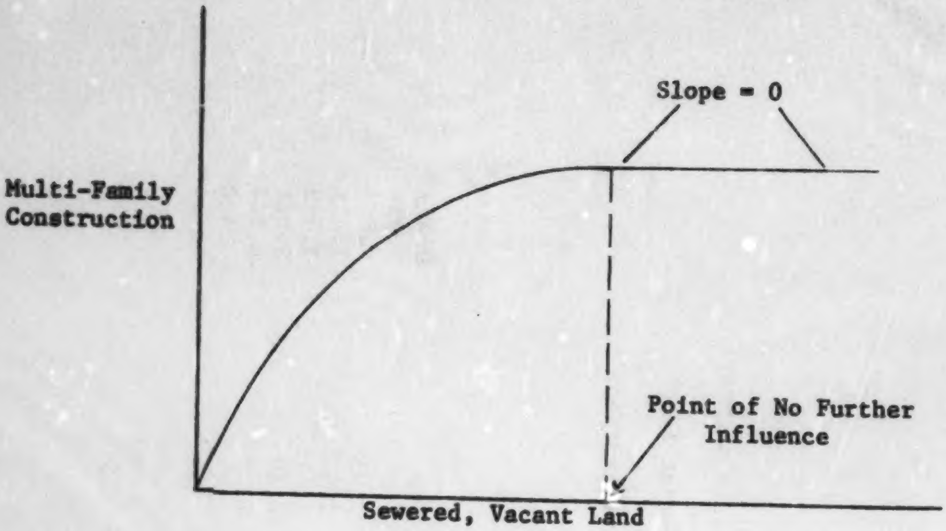
Slope = 0
Multi-Family Construction
Point of No Further Influence
Sewered, Vacant Land

Figure A.1 Hypothetical Non-Linear Influence of Sewer Service

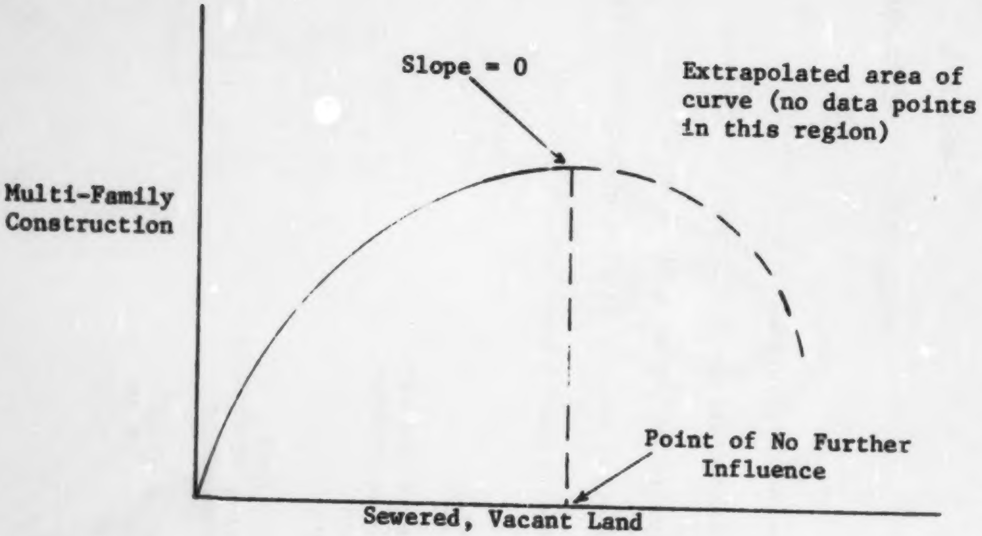
Slope = 0
Extrapolated area of curve (no data points in this region)
Multi-Family Construction
Point of No Further Influence
Sewered, Vacant Land

Figure A.2 Estimated Polynomial Influence of Sewer Service Tested in Regression Analyses

Table A.2

Single-Family Housing Construction

Specification:

Single-family units constructed (1960-1970) =

b_1(base year distance to highway) + b_2(change in distance to highway)

+ b_3(sewered vacant land) + b_4(watered vacant land) + b_5(vacant land)

+ b_6(residential vacancy rate) + b_7(multi-family housing construction)

+ b_8(industrial land conversion) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Base Year Distance to Highway	b_1 = 11.8	37.0	0.319
Change in Distance to Highway	b_2 = 14.8	44.2	0.334
Sewered Vacant Land	b_3 = 0.283	0.058	4.857
Watered Vacant Land	b_4 = 0.052	0.035	1.481
Vacant Land	b_5 = -0.045	0.016	-2.763
Residential Vacancy Rate	b_6 = 28.58	14.12	2.024
Multi-Family Housing Construction	b_7 = -0.036	0.080	-0.447
Industrial Land Conversion	b_8 = -1.115	0.779	-1.430

Constant = -93.5
R^2 = 0.26
F* = 7.56

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* F.01 = 2.56

Table A.3

Single-Family Housing Construction

Specification:

Single-family units constructed (1960-1970) =

b_1(base year distance to highway) + b_2(change in distance to highway)

+ b_3(sewered vacant land) + b_4(sewered vacant land)^2 + b_5(watered vacant land)

+ b_6(watered vacant land)^2 + b_7(vacant land) + b_8(vacant land)^2 + b_9(residential vacancy rate)

+ b_{10}(multi-family housing construction) + b_{11}(industrial land conversion) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Base Year Distance to Highway	$b1 = 6.1$	35.7	0.171
Change in Distance to Highway	$b2 = 14.1$	41.6	0.340
Sewer Service	$b3 = 0.72$	0.13	5.699
(Sewer Service)^2	$b4 = -0.10\text{x}10^{-3}$	$0.25\text{x}10^{-4}$	-4.174
Water Service	$b5 = 0.094$	0.068	1.379
(Water Service)^2	$b6 = 0.82\text{x}10^{-6}$	$0.43\text{x}10^{-5}$	0.189
Vacant Land	$b7 = -0.072$	-0.042	-1.740
(Vacant Land)^2	$b8 = 0.16\text{x}10^{-5}$	$0.21\text{x}10^{-5}$	0.764
Residential Vacancy Rate	$b9 = 9.71$	13.74	0.706
Multi-Family Housing Construction	$b10 = -0.055$	-0.075	-0.734
Industrial Land Conversion	$b11 = -1.48$	0.75	-1.986

Constant = -124
R^2 = 0.37
F* = 9.05

* Critical t values are:
$t_{.10} = 1.282$
$t_{.05} = 1.645$
$t_{.01} = 2.326$

* $F_{.01} = 2.15$

Table A.4

Single-Family Housing Construction, Normalized

Specification:

(Single-family units constructed/total land) =

b_1(base year distance to highway) + b_2(change in distance to highway)

+ b_3(sewered vacant land/total land) + b_4(sewered vacant land/total land)^2

+ b_5(watered vacant land/total land) + b_6(watered vacant land/total land)^2

+ b_7(vacant land/total land) + b_8(vacant land/total land)^2 + b_9(residential vacancy rate)

+ b_{10}(multi-family housing construction/total land)

+ b_{11}(industrial land conversion/total land) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Base Year Distance to Highway	$b_1 = 0.014$	0.021	0.698
Change in Distance to Highway	$b_2 = 0.008$	0.025	0.328
Sewered Vacant Land/Total Land	$b_3 = 1.27$	0.26	4.813
(Sewered Vacant Land/Total Land)^2	$b_4 = -0.27\text{x}10^{-3}$	$0.75\text{x}10^{-4}$	-3.589
Watered Vacant Land/Total Land	$b_5 = 0.22$	0.24	0.915
(Watered Vacant Land/Total Land)^2	$b_6 = 0.12\text{x}10^{-7}$	$0.28\text{x}10^{-4}$	--
Vacant Land/Total Land	$b_7 = 0.31$	0.20	1.509
(Vacant Land/Total Land)^2	$b_8 = 0.53\text{x}10^{-5}$	$0.15\text{x}10^{-4}$	0.344
Residential Vacancy Rate	$b_9 = -0.027$	0.09	-3.000
Multi-Family Construction/Total Land	$b_{10} = -0.072$	0.023	-3.178
Industrial Land Conversion/Total Land	$b_{11} = -1.46$	0.94	-1.545

Constant = -0.22
R^2 = 0.51
F^* = 16.2

* Critical t values are: .10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* F.01=2.15

Sewer service and water service are important determinants of single-family construction in these equations. The non-linear formulation of sewered vacant land works according to expectations; the variable exerts large influence for small values (about .72 new dwelling units per sewered vacant acre in Table A.3), but diminishes in its marginal effect until additional sewered vacant land causes no further construction, starting at 3,600 acres sewered and vacant.* Watered vacant land, on the other hand, appears to have a much more linear effect, since the squared term in Tables A.3 and A.4 are very small and insignificant. Because the water and sewer variables are highly colinear, the relatively modest t statistics for watered vacant land do not necessarily indicate a true lack of significance.

The other policy variables, base year distance to highway and change in distance to highway, are insignificant in all tests. While this could have been caused in part by collinearity, all the coefficients are quite small, indicating that the influence of the variables was minor, regardless of their true levels of significance. A tentative interpretation of this result is that the highway system in the Denver region was sufficiently well established early in the 1960's to prevent any new highways from having major effects on single-family construction. This is consistent with the general conclusion of previous research, although our own findings indicated that, on the average, highways have a somewhat larger influence than these coefficients indicate.

The competition variables, multi-family construction and industrial land conversion, have the appropriate negative sign in all three equations. However, the former is highly significant only in the normalized formulation (Table A.4). Residential vacancy rate has an unexpected positive influence in the unnormalized equations, indicating that high vacancy rates did not tend to reduce single-family construction. In the normalized version, however, vacancy rate has a significant negative effect on single-family units constructed per acre of land in each district. Similarly, the influence of vacant land is negative for the unnormalized specifications and positive in the normalized equations (with no apparent non-linearities).

The normalized equation appears slightly better in terms of significance of coefficients and explanatory power. The differences in signs of coefficients between the unnormalized and normalized equations are caused largely by the fact that small districts are given more weight in the normalized version. Thus it appears that in the smaller, central districts, vacancy rates were negatively correlated with construction, while in larger outer districts, construction of substantial subdivisions occurred regardless of existing high vacancy rates.

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* This value is derived by taking the first derivative of the two sewered vacant land terms and setting it equal to zero to find the maximum of the parabola.

Similarly, when the larger districts are given equal weight in the regression, substantial amounts of vacant land indicate a lack of demand rather than an abundance of inexpensive sites. In the normalized regression, on the other hand, the proportion of vacant land (emphasizing smaller districts) has a positive influence. These results are not contradictory, as they might first appear.

These findings were used to construct two more specifications for single-family construction. Because there was no clear preference for either the normalized or unnormalized equations, both forms were retained. Variables that were insignificant or had inappropriate coefficients were omitted, with the exception of change in distance to highway. This policy variable was retained to attempt to determine whether collinearity with base year distance to highway had biased initial results. The two new estimated equations are shown in Tables A.5 and A.6.

In the unnormalized form (Table A.5) all variables are significant with the exception of change in distance to highway, and all have appropriate signs. Sewered vacant land has a non-linear influence, as discussed previously. The other variables are linear in their effects. The F statistic is highly significant, confirming the accuracy of the specification as a whole, while the coefficient of determination (R^2) is quite adequate for so simple a model.

The normalized equation (Table A.6), however, is slightly better for several reasons. Two additional variables representing local market conditions -- residential vacancy rate and multi-family construction -- enter significantly in the regression. Since both are theoretically important, the former as a demand indicator and the latter as a competition factor, their inclusion strengthens the specification. More important, change in distance to highway, a policy variable, now has the hypothesized influence and is statistically significant. We can speculate that collinearity with base year distance to highway biased the level of significance in the previous regression (Table III.3), although it is impossible to verify this with certainty. In addition, this specification has a substantially higher R^2 and a somewhat larger F statistic.

The R^2 (.47) is even more impressive in view of the fact that the residual errors for this regression are highly heteroscedastic. Heteroscedasticity is the condition in which errors have non-constant variance. In cross-sectional regressions, the most common cause of heteroscedasticity is correlation between errors and some other variable. In our case, the residuals are negatively correlated with district size -- small districts have a much greater variation in residuals than larger districts. This reduces the efficiency of the estimate, implying lower t statistics and R^2. However, the estimated coefficients are unbiased, so we can assume that they are representative of actual relationships, and probably more accurate than the t statistics and R^2 imply.

Table A.5

Single-Family Housing Construction

Specification:

Single-family units constructed =

b_1(change in distance to highway) + b_2(sewered vacant land) + b_3(sewered vacant land)^2

+ b_4(watered vacant land) + b_5(vacant land) + b_6(industrial land conversion)

+ constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Change in Distance to Highway	$b_1 = 17.5$	23.9	0.730
Sewered Vacant Land	$b_2 = 0.67$	0.082	8.171
(Sewered Vacant Land)^2	$b_3 = -0.94\text{x}10^{-4}$	$0.16\text{x}10^{-4}$	-5.824
Watered Vacant Land	$b_4 = 0.11$	0.033	3.249
Vacant Land	$b_5 = -0.041$	0.014	-2.795
Industrial Land Conversion	$b_6 = -1.65$	0.72	-2.299

Constant = -81.3
R^2 = 0.36
F^* = 16.5

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* F.01 = 2.73

Table A.6

Single-Family Construction, Normalized

Specification:

(Single-family units constructed/total land) =

b_1(change in distance to highway) + b_2(sewered vacant land/total land)

+ b_3(sewered vacant land/total land)^2 + b_4(watered vacant land/total land)

+ b_5(vacant land/total land) + b_6(multi-family units constructed/total land)

+ b_7(industrial land conversion/total land) + b_8(residential vacancy rate) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Change in Distance to Highway	b_1 = 0.026	0.015	1.746
(Sewered Vacant Land/Total Land)	b_2 = 1.12	0.392	2.862
(Sewered Vacant Land/Total Land)^2	b_3 = -0.452	0.431	-1.048
(Watered Vacant Land/Total Land)	b_4 = 0.237	0.163	1.455
(Vacant Land/Total Land)	b_5 = 0.297	0.131	2.272
(Multi-Family Units Constructed/Total Land)	b_6 = -0.068	0.023	-2.924
(Change in Industrial Land/Total Land)	b_7 = -1.86	0.974	-1.906
Residential Vacancy Rate	b_8 = -0.028	0.009	-3.088

Constant = -0.176
R^2 = 0.47
F* = 19.2

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* $F_{.01}$ = 2.50

2. Multi-Family Housing Construction

A similar series of regressions was made to derive an equation for multi-family housing construction. Table A.7 presents results for the final regression. Generally, the equations for multi-family construction were disappointing relative to the other forms of land use change. There is no simple theoretical or empirical reason for this shortcoming, nor does it extend to results for analyses in other regions.

Residential vacancy rate was the only consistent variable in these tests. The sewer service variables had the appropriate positive sign, but most had modest levels of significance. One problem with multi-family housing may be inferred from the F statistic. All were significant at the 5 percent level or more. In contrast, the t values are insignificant at the five percent level, with the exception of residential vacancy rate. Since t values are biased by multi-collinearity while F statistics are not, the results seem to suggest that intercorrelation among the independent variables is a principal cause of low levels of significance. On the other hand, the low proportion of explained variation in each case indicates both that important factors have been omitted from the equations and that the observed multi-family construction in the region was erratic and uneven from district to district, creating "noisy" data.

Another possible cause of low R^2's is heteroscedasticity, which reduces the efficiency of the estimates. The technique for preventing heteroscedasticity is Weighted Least Squares (WLS), in which reliable observations are given more weight in regressions than unreliable ones. We tried a number of WLS regressions weighting larger districts over smaller districts to correct for the correlation between residuals and district size. However, neither the t statistics nor the R^2's were improved significantly.

In the final specification, the number of explanatory variables was reduced to prevent some of the multi-colinearity problems. The water service variables were omitted, and the linear form for vacant land was selected over the polynomial one. Sewered vacant land was kept in the non-linear form because of the slight evidence that this was more appropriate.

3. Commercial Land Conversion

Results of the final regression for conversion of land to commercial use are shown in Table A.8. In addition to the usual explanatory variables, single-family housing construction was used to represent co-location of commerce with new residential development. We expected the coefficients of this variable to be positive.

Examination of the residuals for earlier regressions revealed extreme heteroscedasticity. For this reason, a Weighted Least Squares

Table A.7

Multi-Family Construction, Unnormalized Revised Form

Specification:

Multi-family units constructed =

b_1 (change in distance to highway) + b_2 (sewered vacant land)

+ b_3 (sewered vacant land)^2 + b_4 (vacant land)

+ b_5 (residential vacancy rate) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Change in Distance to Highway	$b_1 = -8.94$	24.1	-0.371
Sewered Vacant Land	$b_2 = 0.069$	0.087	0.798
(Sewered Vacant Land)2	$b_3 = -0.93 \times 10^{-5}$	0.16×10^{-4}	-0.568
Vacant Land	$b_4 = -0.011$	0.013	-0.848
Residential Vacancy Rate	$b_5 = 39.41$	13.49	-2.920

Constant = 518.0
R^2 = 0.07
F* = 2.53

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* F.01 = 2.90

Table A.8

Commercial Land Conversion, Weighted by District Size

Specification:

Acres converted to commercial use =

b_1 (change in distance to highway) + b_2 (sewered vacant land)

+ b_3 (sewered vacant land)^2 + b_4 (vacant land)

+ b_5 (single-family units constructed) + b_6 (1/total land) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Change in Distance to Highway	$b_1 = -1.45$	0.443	-3.265
Sewered Vacant Land	$b_2 = 0.41 \times 10^{-2}$	0.16×10^{-2}	2.602
(Sewered Vacant Land)^2	$b_3 = -0.59 \times 10^{-6}$	0.21×10^{-6}	-2.866
Vacant Land	$b_4 = -0.28 \times 10^{-3}$	0.19×10^{-3}	-1.426
Single Family Units Constructed	$b_5 = 0.011$	0.002	4.540
(1/Total Land)	$b_6 = 7493$	--	--

Constant = 5.34
R^2 = 0.30
F* = 12.3

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* $F_{.01}$ = 2.73

approach was taken in a new series of regressions. The general form of the WLS specification was to multiply observations of all variables -- dependent and explanatory -- by total land in each district. This weights observations in the statistically more reliable larger districts more than those for smaller districts, allowing more efficient estimation of parameters. At the same time, the coefficients are unbiased estimators of true parameters of the original (i.e., unweighted) specification.*

Sewer service and single-family construction are highly significant. Change in distance to highway has the incorrect sign, but is very small in magnitude. The variable 1/total land is a corrective term for the influence of district size on commercial development. The R^2 and F statistic are adequate.

4. Industrial Land Conversion

The regression equation for conversion of land to industrial use is shown in Table A.9. For the first time, base year distance to highway is a significant variable. The importance of highways for industrial development is probably caused by the fact that highways serve several purposes for industry, including transportation of employees, raw materials, and finished products to markets.

Industry also shows the greatest sensitivity to water service. Apparently, industrial development in the Denver region is strongly dependent on public water supply. Sewer service, on the other hand, has a very small influence on industrial land conversion. Because the sewer and water service variables are highly correlated (r - .7), the low t statistic for sewered vacant land may be a result of collinearity. It should be noted that this collinearity prevents the regression from distinguishing between the effect of water and sewer service. Therefore, some portion of the effect of watered vacant land reflected in its coefficient may be attributable to sewered vacant land, and *vice versa*. However, the estimated coefficients, which are statistically unbiased, suggest not unreasonably that sewer service is of relatively little importance compared to water service.

5. Transformation of the Equations

As a final step in the regression analyses, the equations were respecified using a stock formulation with future year amounts of land use as dependent variables rather than the first difference form in which land use changes are estimated. The stock formulation places land use changes and secondary effects in the context of overall conditions in a district and is therefore more appropriate for evaluating the significance of impacts. Clearly the importance of any secondary

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* For a basic discussion of Weighted Least Squares, see: Wannacott, R. J., and T. H. Wannacott, *Econometrics*, Chapter 6, John Wiley and Sons, Inc., New York, 1970.

Table A.9

Industrial Land Conversion

Specification:

Acres converted to industrial use =

b_1 (base year distance to highway) + b_2 (change in distance to highway)

+ b_3 (sewered vacant land) ÷ b_4 (watered vacant land) + b_5 (vacant land)

+ b_6 (vacant land)^2 + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Base Year Distance to Highway	$b_1 = -8.5$	3.5	-2.407
Change in Distance to Highway	$b_2 = 10.6$	4.1	2.573
Sewered Vacant Land	$b_3 = -0.27 \times 10^{-3}$	0.55×10^{-2}	-0.049
Watered Vacant Land	$b_4 = 0.019$	0.003	6.099
Vacant Land	$b_5 = 0.007$	0.003	2.203
(Vacant Land)^2	$b_6 = 0.45 \times 10^{-6}$	0.14×10^{-6}	-3.175

Constant = 13.8
R^2 = 0.34
F* = 14.8

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* F.01 = 2.73

effects depends upon the conditions in which they occur. An increase in multi-family construction of 500 units, for example, has a much greater significance in a largely undeveloped area than in one with a substantial existing stock of apartments.

While the use of future year stocks as dependent variables and base year stocks as explanatory variables greatly improves the accuracy and stability of the resulting equations, it is important to recognize that this has no effect on the accuracy of the equations in estimating land use changes. Any additional explanatory power as reflected in the coefficients of determination and F statistics are attributable to the altered format. The reformulated equations are shown in Tables A.10-A.13.

6. Interpretation of the Final Equations

In reviewing results of the final regressions, perhaps the most important characteristic in a general sense is the significant influence of policy variables in all equations. This is concrete empirical evidence that public investments in highways, sewers, and water supply systems have played an important role in shaping the pattern of urban growth in the Denver region. While our findings suggest that the influence of new highways may be diminishing, water resource investments will probably continue to have a major effect on urban development in the forseeable future.

In contrast to our original hypotheses, both highway and sewer investments have substantial effects on single-family housing construction. New water supply facilities also played an important role in determining the location of single-family housing. The effects of investments on the other forms of land use are less substantial, although far from insignificant. The only real inconsistency between anticipated relationships and regression results is the lack of influence of highways on multi-family housing construction. As mentioned earlier, this problem probably was caused in part by multi-collinearity. In addition, however, the highway service measures used -- proximity to highways -- may simply be too gross to reflect the actual relationship. Previous research suggests that multi-family housing construction is sensitive to "pockets" of accessibility such as interchanges. Our variables are not precise enough to capture this phenomenon.

An indication of the importance of the policy variables in the equations is given in Table A.14. The percentages shown reflect the influence of public investments relative to all of the factors contributing to land use change. Each explanatory variable causes some component -- positive or negative -- of the overall ten-year change. The values in the Table reflect the proportion of all such components attributable to public investments for each form of construction assuming average conditions.

Table A.10

Forecast Year Single Family Housing Units

Specification:

Forecast year single family units/total land =

b_1 (base year single family units/total land) + b_2 (change in distance to highway)

+ b_2 (sewered vacant land/total land) + b_4 (watered vacant land/total land)

+ b_5 (vacant land/total land) + b_6 (multi-family units constructed/total land)

+ b_7 (change industrial land/total land) + b_8 (residential vacancy rate) + constant

Explanatory Variables	Regression Coeffient	Standard Error	t Statistic*
Single Family Units, 1960/Total Land	b_1 = 0.885	0.033	27.03
Change in Distance to Highway	b_2 = 0.025	0.015	1.722
Sewered Vacant Land/Total Land	b_3 = 0.74	0.16	4.532
Watered Vacant Land/Total Land	b_4 = 0.186	0.157	1.188
Vacant Land/Total Land	b_5 = 0.069	0.14	0.502
Multi-Family Units Constructed/Total Land	b_6 = -0.044	0.023	-1.922
Change in Industrial Land/Total Land	b_7 = 2.03	0.933	-2.174
Residential Vacancy Rate	b_8 = -0.034	0.009	-3.664

Constant = 0.136
R^2 = 0.91
F* = 227.0

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* F.01 = 2.50

Table A.11

Forecast Year Multi-Family Housing Units - Unnormalized

Specification:

Forecast year multi-family units =

b_1 (base year multi-family units) + b_2 (change in distance to highway)

+ b_3 (sewered vacant land) + b_4 (sewered vacant land)^2 + b_5 (vacant land)

+ b_6 (residential vacancy rate) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Multi-Family Units, 1960	$b_1 = 1.13$	0.045	25.31
Change in Distance to Highway	$b_2 = -1.49$	23.8	-0.062
Sewered Vacant Land	$b_3 = 0.155$	0.090	1.719
(Sewered Vacant Land)^2	$b_4 = -0.22 \times 10^{-4}$	0.16×10^{-4}	-1.316
Vacant Land	$b_5 = -0.57 \times 10^{-2}$	0.13×10^{-1}	-0.451
Residential Vacancy Rate	$b_6 = -48.94$	13.69	-3.575

Constant = 461
R^2 = 0.81
F* = 125.1

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* $F_{.01}$ = 2.73

Table A.12

Forecast Year Commercial Land (Weighted by District Size)

Specification:

Forecast year commerical acres =

b_1 (base year commercial acres) + b_2 (base year distance to highway)

+ b_3 (sewered vacant land) + b_4 (sewered vacant land)^2

+ b_5 (single-family units constructed) + b_6 (1/total land) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Base Year Commercial Land	b_1 = 1.05	0.064	16.45
Base Year Distance to Highway	b_2 = -1.46	0.37	-3.911
Sewered Vacant Land	b_3 = 0.23×10^{-2}	0.16×10^{-2}	1.423
(Sewered Vacant Land)^2	b_4 = -0.42×10^{-6}	0.20×10^{-6}	-2.104
Single-Family Construction (1960-70)	b_5 = 0.011	0.002	4.602
(1/Total Land)	b_6 = 7882	-	-

Constant = 7.9
R^2 = 0.75
F* = 85.2

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* F.01 = 2.73

Table A.13

Forecast Year Industrial Land

Specification:

Forecast year industrial acres =

b_1 (base year industrial acres) + b_2 (base year distance to highway)

+ b_3 (change in distance to highway) + b_4 (watered vacant land)

+ b_5 (vacant land) + b_6 (1/total land) + constant

Explanatory Variables	Regression Coefficient	Standard Error	t Statistic*
Base Year (1960) Industrial Land	$b_1 = 1.07$	0.015	69.38
Base Year Distance to Highway	$b_2 = -13.1$	3.6	-3.646
Change in Distance to Highway	$b_3 = 14.4$	4.1	3.519
Watered Vacant Land	$b_4 = 0.016$	0.002	6.134
Total Vacant Land	$b_5 = -0.98 \times 10^{-3}$	0.002	-0.651
(1/Total Land)	$b_6 = -12356$	5500	-2.246

Constant = 37.2
R^2 = 0.97
F* = 1.01

* Critical t values are:
.10 level = 1.282
.05 level = 1.645
.01 level = 2.326

* $F_{.01} = 2.73$

Table A.14

Importance of Public Investments Relative to All Factors Contributing to Change

	Highway	Sewer*	Water*
Single-Family Housing Construction	4.6%	23.0%	6.8%
Multi-Family Housing Construction	-	8.2%	-
Commercial Land Conversion	5.7%	6.6%	-
Industrial Land Conversion	15.0%	-	16.6%

*Assumes no service existed in base year.

As the Table shows, under average conditions public investments exert small to moderate influence on construction. Values range 4.6 to 23 percent of overall components of change. Under extreme conditions, of course, the relative influence of each form of investment might be much higher.

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APPENDIX B

HISTORICAL APPLICATION OF THE EQUATIONS

Retrospective projections of land use changes during the period 1960-1970 were made for four districts in the Denver region to provide examples of the accuracy of the equations and of problems in their use. Projected changes are compared with those actually occurring during the interval and impacts of historical investments are calculated.

The four districts are representative of the variations in size, base year characteristics, and levels of public investments found in the region. They range from small, largely developed portions of the urban core to large, undeveloped outlying areas. Figure B.1 shows the boundaries of the areas used; Table B.1 lists their characteristics as required for applying the equations. Each district is briefly described below.

A. Sample Districts

District 101 (West Colfax Avenue). District 101 is typical of the many small central zones used in the regression analyses. It is bounded by Sheridan and Federal Boulevards on the west and east, and comprises about one square mile of land. In 1960 it was devoted largely to residential use, with a slight predominance of single-family housing, and contained only a small amount of vacant land.

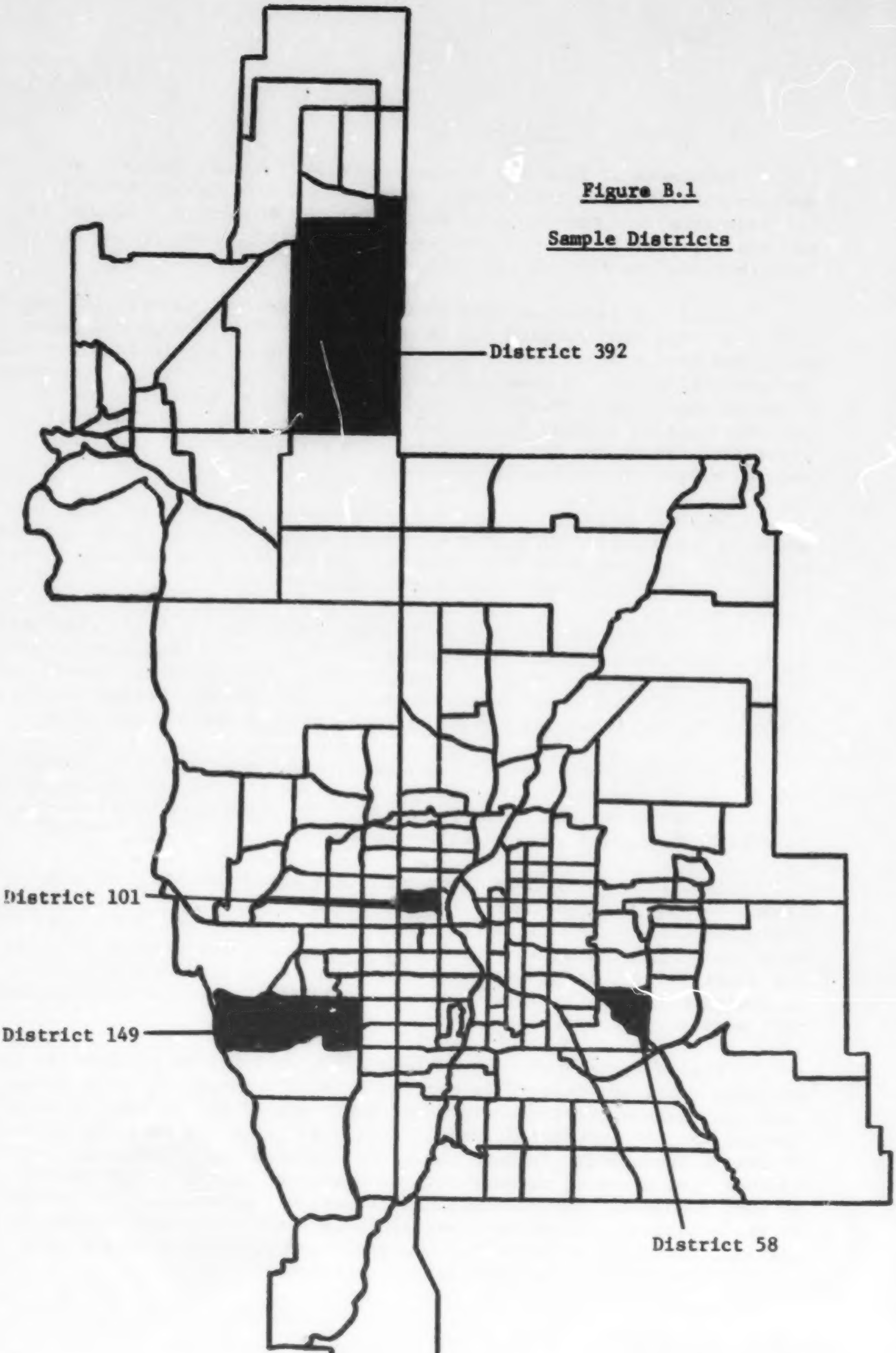
District 58 (Parker Road). District 58, some 2-1/2 square miles in size, lies in the southeast suburbs. It was largely vacant in 1960, but already had substantial water and sewer service, as well as excellent accessibility via Interstate 25. It was, therefore, a prime location for new development in the decade.

District 149 (Southwest Lakewood). District 149 comprises approximately 11 square miles south and west of Lakewood. It is bordered by Wadsworth Boulevard, West Jewell Avenue, Bear Creek, and Hogback Ridge. In 1960, it contained scattered residences, commerce, and industry, but had nearly 2,000 acres of vacant, sewered land. During the 1960-1970 period, a substantial increase in water service and construction of Route 285 heightened the district's attractiveness for development.

District 392 (East Boulder County). District 392 is the largest of our sample districts, containing more than 35 square miles. It is bounded by the Boulder County line to the east, by Arapahoe Road to the south, and by 75th Street and St. Vrain Creek to the west and north. It was 93 percent vacant in 1960, but contained substantial sewer and water service for new growth.

Figure B.1

Sample Districts


District 392
District 101
District 149
District 58

B. Results of Applications

Forecasts of land use changes 1960-1970, actual changes, and measurements of historical impacts are presented in Tables B.2-B.5. The forecasts were made in accordance with the procedures outlined in the report; impacts are measured as the proportion of projected change "attributable" to the relevant investment.

Table B.2 indicates that District 101 received substantial multi-family housing construction during the period. This change was underestimated by the equations, while the demolition of single-family housing was overestimated. In general, forecasts of demolition (i.e., negative changes) should be viewed with suspicion, since the equations do not reflect the non-economic forces behind urban renewal. Estimates of industrial and commercial land conversion correspond well with the modest changes that actually occurred.

Because District 101 was fully sewered and watered in 1960, no additional secondary effects from new investment of these types occurred during the ten year interval. Highway investments affected only industrial land, and that impact was quite small.

In District 58 (Table B.3), a significant amount of single-family housing was constructed. The equations forecast this with some accuracy, as well as the lesser amounts of multi-family construction. Commercial and industrial land remained stable during the decade. Modest increases forecast by the equations for these types of land use did not occur.

Sewer and water facility investments had some impact on single-family, multi-family, and industrial development. The effects are quite modest. Similarly, the construction of I-225 stimulated small increases in single-family and industrial development.

In District 149, new development was again dominated by single-family housing construction. The forecasts reflect this trend, but overestimate both single- and multi-family construction. In particular, the equations suggest a major potential for apartment construction that was not fulfilled. This may have occurred because of land use controls excluding multi-family housing from the district. Smaller overestimates were made for industrial and commercial land.

This district provides an indication of possible problems in expressing secondary impacts as percent of total change. In some cases, land use changes attributed to investments exceed 100 percent of total changes, as for industrial land in this district. The positive influences of public investments in such cases are countered by other negative factors, for example, vacancy rate or base year distance to highway. We must emphasize that the marginal effects of investments, as estimated by the equations, do not necessarily imply actual land use changes. Instead, they reflect potential changes whose occurrence depend upon the overall character of the district in question.

The same problem of expressing impact as a percent of total change occurs in District 392. The marginal influence of highways expressed as percent of projected construction exceeds 100 percent. In this instance, a large potential secondary effect was limited by other features of the district, most notably the high vacancy rate. Forecasts for the district conform roughly to actual changes.

C. Summary

In reviewing these retrospective applications, we must emphasize that land use forecasts should be viewed as general indications of the direction and magnitude of likely changes rather than point predictions. Estimated changes are potential events that may be altered by forces not reflected in the equations. Wherever possible, forecasts should be evaluated and adjusted through examination of local conditions such as zoning, other land use controls, topography, and public policies. Finally, calculations of secondary effects must be assessed in light of the overall estimated land use changes.

Table B.1

District Characteristics for Sample Application

	Districts			
Variable	No. 58	No. 101	No. 149	No. 392
Total Land (acres)	1,681	676	7,086	23,808
1960 Vacant Land (acres)	1,253	77	5,044	22,069
1960 Sewered Vacant Land	1,233	77	1,955	921
1960-1970 Change in Sewered Vacant Land	20	0	1,021	133
1960 Watered Vacand Land	721	77	0	2,693
1960-1970 Change in Watered Vacant Land	532	0	2,612	1,286
1960 Residential Vacancy Rate	8.7	4.0	8.4	10.3
1960 Distance to Highway	2.6	1.0	3.6	6.0
1960-1970 Change in Distance to Highway	0.25	0.25	1.9	4.1
1960 Single Family Units	224	1,644	150	215
1960 Multi-Family Units	16	1,115	4	9
1960 Commercial Land	1	19	3	0
1960 Industrial Land	69	12	67	3

Table B.2

Results of Historical Applications

District No. 101

	Industrial Land (Acres)		Multi-Family Housing (Units)		Single-Family Housing (Units)		Commercial Land (Acres)	
	Estimate	Actual	Estimate	Actual	Estimate	Actual	Estimate	Actual
1970 Total	24	24	1537	2129	1507	1547	37	43
1960-1970 Change	12	12	422	1014	-137	-97	18	24
Highway Impact*	30%		--		0		0	
Sewer Impact*	--		0		0		0	
Water Impact*	0		--		0		--	

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*Measured as percentage of 1960-1970 projected change.

Table B.3

Results of Historical Applications

District No. 58

	Industrial Land (Acres)		Multi-Family Housing (Units)		Single-Family Housing (Units)		Commercial Land (Acres)	
	Estimate	Actual	Estimate	Actual	Estimate	Actual	Estimate	Actual
1970 Total	92	74	212	271	1151	866	21	1
1960-1970 Change	23	5	196	255	927	642	20	0
Highway Impact*	16%		--		1%		1%	
Sewer Impact*	--		1%		2%		0%	
Water Impact*	37%		--		11%		--	

*Measured as percentage of 1960-1970 projected change.

Table B.4

Results of Historical Applications

District No. 149

	Industrial Land (Acres)		Multi-Family Housing (Units)		Single-Family Housing (Units)		Commercial Land (Acres)	
	Estimate	Actual	Estimate	Actual	Estimate	Actual	Estimate	Actual
1970 Total	124	73	306	0	2430	1403	32	6
1960–1970 Change	57	6	302	-4	2280	1253	29	3
Highway Impact*	48%		—		18%		14%	
Sewer Impact*	—		17%		33%		0%	
Water Impact*	73%		—		22%		—	

---

*Measured as percentage of 1960–1970 projected change.

Table B.5

Results of Historical Applications

District No. 392

	Industrial Land (Acres)		Multi-Family Housing (Units)		Single-Family Housing (Units)		Commercial Land (Acres)	
	Estimate	Actual	Estimate	Actual	Estimate	Actual	Estimate	Actual
1970 Total	62	58	0**	45	1095	601	10	0
1960-1970 Change	59	55	-9	36	880	386	10	0
Highway Impact*	100%		—		100+		100+	
Sewer Impact*	—		0		11%		2%	
Water Impact*	35%		—		27%		—	

*Measured as percentage of 1960-1970 projected change.

**Negative forecast adjusted to 0.

APPENDIX C

1970 DENVER REGIONAL DATA

The following computer print-out contains a complete listing of the 1970 data necessary for applying the regression equations. The data were collected from the Denver EMPIRIC model, developed by the Denver Regional Council of Governments, and from the U.S. Census of Housing. The analysis districts representing observations for each variable correspond to EMPIRIC calibration districts, shown in Figure C.1 (District 192, the Rocky Mountain Arsenal, was deleted for our statistical analyses).

Code names for each variable are printed at the top of columns. The code is:

OBS = observation number
DISTRICT = EMPIRIC district number
SFUNIT70 = single-family housing units, 1970
MFUNIT70 = multi-family housing units, 1970
CLU70 = commercial land, 1970 (acres)
ILU70 = industrial land, 1970 (acres)
VLU70 = vacant, developable land, 1970 (acres)
TVRATE70 = residential vacancy rate, 1970
THH70 = total households, 1970
TOTLU = total land, 1970 (acres)
SEWER70 = sewer service area, 1970 (acres)
WATER70 = water service area, 1970 (acres)
URBAN70 = urban land, 1970 (acres)
D70 = distance to highway, 1970 (miles)

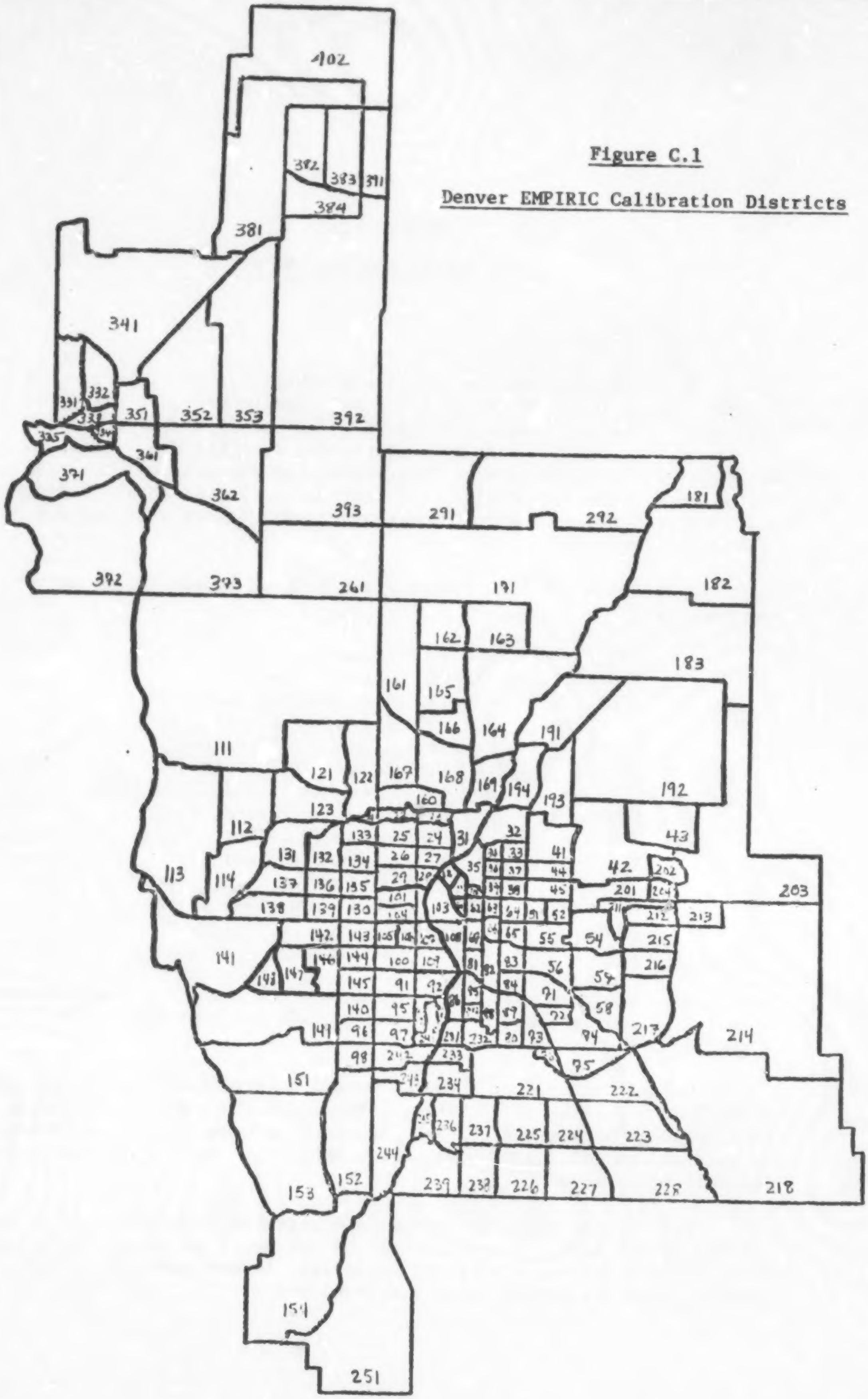
Each row in the print-out lists values for the characteristics (variables) in a single district; columns contain all district values for a single variable.

Values for sewered vacant land and watered vacant land are not listed. In the absence of better information, they may be estimated (see Appendix A, pages A15-16) by subtracting urban land from sewered or watered land (SEWER70 or WATER70 - URBAN70). Such estimates entail the following corrections:

(1) If the calculation yields a negative value for sewered or watered vacant land the value should be set equal to zero. The negative value implies that some existing urban land is unsewered; we assume, however, that all served areas are developed.

Figure C.1

Denver EMPIRIC Calibration Districts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(2) If the value is greater than vacant land, it should be corrected to equal vacant land. This occurs when extensive urban land uses not included in URBAN70 are sewered. For example, extensive uses such as hospitals, prisons, airports, etc., may include large grounds. Although these grounds do not require sewer service, they often are within the service areas of sewer lines, particularly in inner, largely developed districts. While no use is made of the capacity of the sewer lines, the presence of extensive uses prevents other forms of development. Since such land is not available on the private market, it should not be represented as sewered or watered vacant land.

(3) If a district contains no sewer or water service in 1970, existing urban land must be subtracted from the proposed service area of new sewers and water lines in calculating policy variables (i.e., base year + change in sewered and watered vacant land). This assumes that new investments will serve existing (1970) urban land users as well as vacant areas. In all other cases, the value of 1970 (base year) sewered or watered vacant land is simply added to the proposed increase in service area to obtain policy variable values.

Residential vacancy rates were not measured directly, but were estimated from Census data on households and housing units (see Appendix A). As a result of multiple households residing in single housing units, as well as sampling inconsistencies, some of the vacancy rates are negative. In our regression analyses, these negative rates were set equal to zero.

A final problem concerning the data involves single- and multifamily housing units. Values were derived from the 1970 Census of Housing. However, in a few outlying districts, EMPIRIC boundaries did not correspond to census tract boundaries, so estimates were made based on the proportion of land and total households in relevant districts. Any errors in base year values will, of course, be reflected in forecasts. In view, however, of the sampling procedures of the Bureau of Census and the inherent uncertainty of the forecasts, any measurement errors should be insignificant.

1970 DENVER REGIONAL DATA

OBS	DISTRICT	SFUNIT70	MFUNIT70	CLU70	ILU70
1	11.000	26.000	1887.0	I00.00	0.0
2	12.000	0.0	89.000	19.000	195.00
3	21.000	327.00	28.000	8.0000	0.0
4	22.000	1064.0	119.00	7.0000	0.0
5	23.000	1384.0	24.000	26.000	103.00
6	24.000	2937.0	1063.0	18.000	5.0000
7	25.000	3091.0	907.00	18.000	14.000
8	26.000	2818.0	1476.0	35.000	3.0000
9	27.000	2112.0	2123.0	35.000	55.000
10	28.000	563.00	687.00	15.000	105.00
11	29.000	1907.0	1096.0	8.0000	0.0
12	30.000	191.00	3991.0	15.000	18.000
13	31.000	984.00	298.00	9.0000	626.00
14	32.000	1723.0	234.00	34.000	737.00
15	33.000	1233.0	306.00	7.0000	13.000
16	34.000	1371.0	402.00	10.000	114.00
17	35.000	1702.0	3681.0	76.000	355.00
18	36.000	1552.0	926.00	5.0000	0.0
19	37.000	1186.0	294.00	4.0000	0.0
20	38.000	365.00	1003.0	5.0000	9.0000
21	39.000	665.00	2547.0	18.000	5.0000
22	41.000	1713.0	1020.0	39.000	638.00
23	42.000	25.000	0.0	4.0000	354.00
24	43.000	1317.0	412.00	17.000	189.00
25	44.000	3937.0	98.000	7.0000	10.000
26	45.000	2986.0	642.00	21.000	0.0
27	51.000	1812.0	2693.0	8.0000	1.0000
28	52.000	2120.0	416.00	22.000	5.0000
29	53.000	2144.0	903.00	29.000	1.0000
30	54.000	159.00	548.00	0.0	0.0
31	55.000	2741.0	331.00	2.0000	0.0
32	56.000	2058.0	949.00	133.00	70.000
33	57.000	229.00	1348.0	6.0000	230.00
34	58.000	866.00	271.00	1.0000	74.000
35	61.000	129.00	673.00	20.000	25.000
36	62.000	399.00	11558.	16.000	4.0000
37	63.000	423.00	5258.0	9.0000	2.0000
38	64.000	2265.0	6076.0	15.000	23.000
39	65.000	1202.0	769.00	74.000	2.0000
40	66.000	1123.0	277.00	3.0000	0.0
41	67.000	1530.0	5911.0	19.000	10.000
42	71.000	3252.0	1859.0	49.000	26.000
43	72.000	500.00	203.00	75.000	0.0
44	73.000	2502.0	214.00	54.000	81.000
45	74.000	1056.0	239.00	41.000	65.000
46	75.000	1458.0	209.00	32.000	16.000

47	76.000	491.00	302.00	10.000	10.000
48	80.000	1271.0	111.00	0.0	0.0
49	81.000	2310.0	1521.0	16.000	26.000
50	82.000	2642.0	365.00	7.0000	30.000
51	83.000	1300.0	289.00	27.000	0.0
52	84.000	1685.0	38.000	7.0000	53.000
53	85.000	2190.0	798.00	20.000	76.000
54	86.000	907.00	486.00	43.000	106.00
55	87.000	843.00	399.00	9.0000	0.0
56	88.000	2470.0	1773.0	9.0000	27.000
57	89.000	1786.0	1432.0	22.000	13.000
58	91.000	3107.0	463.00	30.000	0.0
59	92.000	2426.0	532.00	22.000	64.000
60	93.000	21.000	0.0	2.0000	190.00
61	94.000	667.00	74.000	32.000	3.0000
62	95.000	3418.0	16.000	12.000	0.0
63	96.000	1476.0	0.0	7.0000	5.0000
64	97.000	2123.0	39.000	33.000	13.000
65	98.000	159.00	24.000	1.0000	64.000
66	100.00	3289.0	839.00	20.000	65.000
67	101.00	1547.0	2129.0	43.000	24.000
68	102.00	524.00	204.00	24.000	119.00
69	103.00	1425.0	1176.0	41.000	465.00
70	104.00	2007.0	554.00	6.0000	19.000
71	105.00	1613.0	86.000	3.0000	0.0
72	106.00	1544.0	298.00	14.000	0.0
73	107.00	1025.0	348.00	31.000	149.00
74	108.00	1319.0	1973.0	63.000	360.00
75	109.00	2435.0	291.00	49.000	20.000
76	111.00	1776.0	39.000	17.000	715.00
77	112.00	604.00	25.000	1.0000	226.00
78	113.00	1842.0	870.00	74.000	434.00
79	114.00	2096.0	199.00	6.0000	322.00
80	121.00	4310.0	407.00	33.000	193.00
81	122.00	5240.0	696.00	35.000	191.00
82	123.00	3111.0	923.00	60.000	96.000
83	130.00	1135.0	1228.0	58.000	48.000
84	131.00	2563.0	733.00	75.000	88.000
85	132.00	1479.0	471.00	32.000	16.000
86	133.00	2032.0	818.00	79.000	0.0
87	134.00	1898.0	808.00	19.000	9.0000
88	135.00	1954.0	1290.0	106.00	0.0
89	136.00	1472.0	757.00	43.000	1.0000
90	137.00	2069.0	453.00	80.000	87.000
91	138.00	1638.0	454.00	50.000	99.000
92	139.00	1274.0	764.00	59.000	22.000

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 93   140.00     231.00     387.00     25.000     10.000
 94   141.00     1872.0     99.000     90.000     468.00
 95   142.00     1551.0     114.00     14.000     13.000
 96   143.00     1580.0     763.00     60.000     19.000
 97   144.00     1105.0     190.00     99.000    0.0
 98   145.00     2352.0     99.000     16.000    0.0
 99   146.00     2388.0     101.00     26.000     3.0000
100   147.00     1613.0     4.0000     13.000     30.000
101   148.00     1432.0     67.000     20.000     2.0000
102   149.00     1403.0    0.0         6.0000     73.000
103   151.00     277.00     23.000    0.0         248.00
104   152.00     1502.0     38.000     2.0000     142.00
105   153.00     189.00    0.0        0.0         103.00
106   154.00     7.0000    0.0        0.0         3824.0
107   160.00     1318.0     116.00     18.000     107.00
106   161.00     2372.0     23.000     27.000     159.00
109   162.00     1205.0     274.00     23.000     48.000
110   163.00     4698.0     266.00     35.000     90.000
111   164.00     4685.0     75.000     152.00     179.00
112   165.00     1841.0     176.00     75.000     266.00
113   166.00     4253.0     227.00     57.000     33.000
114   167.00     3239.0     713.00     110.00     231.00
115   168.00     1854.0     288.00     57.000     683.00
116   169.00     413.00     53.000     9.0000     480.00
117   171.00     370.00     25.000     17.000     25.000
118   181.00     2158.0     323.00     70.000     161.00
119   182.00     451.00     4.0000     6.0000     128.00
120   183.00     365.00     28.000     17.000     432.00
121   191.00     2349.0     168.00     55.000     572.00
122   193.00     3894.0     639.00     104.00     309.00
123   194.00     745.00     97.000     23.000     521.00
124   201.00     3275.0     2575.0     50.000     29.000
125   202.00     1512.0     86.000     3.0000     11.000
126   203.00     1437.0     151.00     53.000     163.00
127   204.00     639.00     479.00     5.0000     15.000
128   211.00     2757.0     2611.0     66.000     30.000
129   212.00     3245.0     127.00     26.000    0.0
130   213.00     1051.0     140.00     13.000     14.000
131   214.00     136.00     7.0000    0.0         18.000
132   215.00     1367.0     244.00     12.000     6.0000
133   216.00     2081.0     75.000     13.000     23.000
134   217.00     1027.0     100.00     2.0000     79.000
135   218.00     177.00    0.0         3.0000    0.0
136   221.00     1183.0     42.000    0.0         13.000
137   222.00     331.00     10.000     4.0000    0.0
138   223.00     135.00    0.0         6.0000    0.0
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139	224.00	366.00	0.0	2.0000	32.000
140	225.00	1651.0	0.0	22.000	0.0
141	226.00	983.00	0.0	0.0	5.0000
142	227.00	492.00	0.0	0.0	5.0000
143	228.00	10.000	1.0000	3.0000	52.000
144	231.00	895.00	482.00	142.00	89.000
145	232.00	2565.0	1007.0	13.000	0.0
146	233.00	1680.0	796.00	25.000	53.000
147	234.00	3019.0	546.00	53.000	257.00
148	235.00	1351.0	609.00	35.000	90.000
149	236.00	2192.0	1326.0	58.000	55.000
150	237.00	2462.0	313.00	73.000	40.000
151	238.00	1292.0	34.000	25.000	74.000
152	239.00	1071.0	7.0000	2.0000	145.00
153	241.00	759.00	42.000	9.0000	139.00
154	242.00	827.00	122.00	10.000	66.000
155	243.00	1258.0	50.000	30.000	78.000
156	244.00	2059.0	61.000	10.000	193.00
157	251.00	102.00	11.000	2.0000	591.00
158	261.00	2033.0	436.00	64.000	634.00
159	291.00	62.000	1.0000	0.0	26.000
160	292.00	160.00	2.0000	19.000	27.000
161	331.00	1636.0	319.00	6.0000	12.000
162	332.00	2416.0	548.00	57.000	42.000
163	333.00	1422.0	2594.0	169.00	67.000
164	334.00	51.000	670.00	4.0000	0.0
165	335.00	1101.0	1504.0	9.0000	0.0
166	341.00	330.00	10.000	3.0000	232.00
167	351.00	368.00	529.00	143.00	288.00
168	352.00	563.00	443.00	26.000	783.00
169	353.00	539.00	12.000	13.000	65.000
170	361.00	1604.0	3114.0	83.000	56.000
171	362.00	1084.0	40.000	7.0000	181.00
172	371.00	3096.0	237.00	18.000	122.00
173	372.00	1694.0	24.000	20.000	149.00
174	373.00	161.00	7.0000	2.0000	233.00
175	381.00	730.00	31.000	1.0000	83.000
176	382.00	2554.0	1919.0	93.000	98.000
177	383.00	2066.0	768.00	103.00	158.00
178	384.00	436.00	140.00	13.000	152.00
179	391.00	34.000	12.000	0.0	0.0
180	392.00	601.00	45.000	0.0	58.000
181	393.00	2197.0	274.00	54.000	254.00
182	402.00	139.00	4.0000	1.0000	67.000

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OBS    DISTRICT      D70           VLU70         TVRATE70        THH70
   1    11.000      0.87500      0.0            0.14271         1640.0
   2    12.000      0.12500      0.0            0.12360         78.000
   3    21.000      0.25000       18.000       -9.29577E-02     388.00
   4    22.000      0.37500       6.0000        7.60778E-03     1174.0
   5    23.000      0.50000       101.00        1.20739E-02     1391.0
   6    24.000      0.25000       86.000        1.67500E-02     3933.0
   7    25.000      0.25000      0.0            1.92596E-02     3921.0
   8    26.000      0.62500       9.0000        3.74942E-02     4133.0
   9    27.000      0.75000       43.000        5.14758E-02     4017.0
  10    28.000      0.50000       7.0000        7.43999E-02     1157.0
  11    29.000      0.62500       128.00        3.23010E-02     2906.0
  12    30.000       1.3750       5.0000        6.93448E-02     3892.0
  13    31.000      0.0           31.000        3.27613E-02     1240.0
  14    32.000      0.37500       178.00        2.91262E-02     1900.0
  15    33.000      0.50000       20.000        4.54841E-02     1469.0
  16    34.000      0.75000       6.0000        7.21940E-02     1645.0
  17    35.000      0.62500       44.000        9.45569E-02     4874.0
  18    36.000       1.3750       10.000        6.09362E-02     2327.0
  19    37.000       1.2500      0.0            3.31081E-02     1431.0
  20    38.000       2.1250       28.000        4.60526E-02     1305.0
  21    39.000       1.8750       8.0000        5.88418E-02     3023.0
  22    41.000      0.12500       415.00        3.14673E-02     2647.0
  23    42.000      0.12500       2047.0        8.00000E-02     23.000
  24    43.000       1.1250       2772.0        0.14054         1486.0
  25    44.000       1.2500       12.000        2.52788E-02     3933.0
  26    45.000       2.0000       36.000        1.15766E-02     3586.0
  27    51.000       2.8750       15.000        4.92786E-02     4283.0
  28    52.000       2.7500       22.000        2.32650E-02     2477.0
  29    53.000       2.2500       20.000        2.19888E-02     2980.0
  30    54.000       3.1250       116.00        0.16407         591.00
  31    55.000       2.7500       51.000       -2.31120E-02     3143.0
  32    56.000       2.0000       274.00        4.72231E-02     2865.0
  33    57.000       3.0000       912.00        5.32657E-02     1493.0
  34    58.000       2.3750       1133.0        0.71592         323.00
  35    61.000       1.2500      0.0            8.72818E-02     732.00
  36    62.000       1.7500       10.000        8.66438E-02     10921.
  37    63.000       2.3750       5.0000        7.12903E-02     5276.0
  38    64.000       2.8750       10.000        0.30055         5834.0
  39    65.000       2.5000       19.000        2.43531E-02     1923.0
  40    66.000       1.8750      0.0            2.35714E-02     1367.0
  41    67.000       1.2500       8.0000        4.58272E-02     7100.0
  42    71.000      0.87500       126.00        8.25670E-02     4689.0
  43    72.000      0.62500       118.00       -0.67568         1178.0
  44    73.000      0.37500       11.000        3.05596E-02     2633.0
  45    74.000       1.3750       681.00       -0.69112         2190.0
  46    75.000       1.1250       674.00        2.99940E-02     1617.0
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47    76.000        0.12500        59.000       1.26103E-02    783.00
48    80.000         1.3750        71.000       6.72938E-02    1289.0
49    81.000        0.50000        4.0000       3.02793E-02    3715.0
50    82.000        0.87500        22.000       1.69604E-02    2956.0
51    83.000         1.5000        46.000       2.01384E-02    1557.0
52    84.000        0.62500        13.000       4.06268E-03    1716.0
53    85.000        0.37500        9.0000       2.54351E-02    2912.0
54    86.000         1.0000        94.000       0.10840        1242.0
55    87.000         1.0000        8.0000       3.54267E-02    1198.0
56    88.000        0.62500        40.000       2.54537E-02    4135.0
57    89.000        0.37500        52.000       2.64139E-02    3133.0
58    91.000        0.75000        64.000       1.54062E-02    3515.0
59    92.000         1.1250        37.000       6.42326E-03    2939.0
60    93.000         1.5000     0.0             4.76190E-02    20.000
61    94.000         1.7500        40.000      -0.16734        865.00
62    95.000        0.75000        87.000       7.86255E-03    3407.0
63    96.000        0.75000        42.000       3.59079E-02    1423.0
64    97.000        0.62500        14.000       9.71323E-03    2141.0
65    98.000        0.25000        504.00      -1.09290E-02    185.00
66    100.00        0.75000        28.000       3.19767E-02    3996.0
67    101.00        0.75000        31.000       3.21001E-02    3558.0
68    102.00        0.12500     0.0            -1.23626E-02    737.00
69    103.00        0.50000        17.000       3.38331E-02    2513.0
70    104.00        0.62500        86.000       2.96759E-02    2485.0
71    105.00        0.25000        18.000       1.17716E-02    1679.0
72    106.00        0.25000        14.000       2.33442E-02    1799.0
73    107.00        0.25000        68.000       2.62200E-02    1337.0
74    108.00        0.50000        44.000       6.71324E-02    3071.0
75    109.00        0.75000        118.00       1.24725E-02    2692.0
76    111.00         4.3750        26380.       6.88705E-02    1690.0
77    112.00         1.5000        2431.0       2.86168E-02    611.00
78    113.00         2.1250        5569.0      -0.10066        2985.0
79    114.00        0.87500        728.00       1.74292E-02    2255.0
80    121.00         2.5000        1857.0       2.03519E-02    4621.0
81    122.00        0.62500        1384.0       0.24882        4459.0
82    123.00        0.87500        677.00       1.63609E-02    3968.0
83    130.00        0.62500        131.00       3.93567E-02    2270.0
84    131.00        0.75000        632.00       1.21359E-02    3256.0
85    132.00         1.1250        271.00      -1.53846E-03    1953.0
86    133.00        0.25000        127.00       4.42105E-02    2724.0
87    134.00        0.75000        136.00       1.44124E-02    2667.0
88    135.00        0.87500        134.00       3.39088E-02    3134.0
89    136.00         1.6250        126.00       2.37775E-02    2176.0
90    137.00         1.1250        628.00       4.04441E-02    2420.0
91    138.00        0.75000        734.00       3.91969E-02    2010.0
92    139.00        0.62500        198.00       3.23847E-02    1972.0
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93	140.00	0.75000	508.00	5.82524E-02	582.00
94	141.00	0.87500	4662.0	0.10350	1767.0
95	142.00	0.37500	197.00	7.20720E-03	1653.0
96	143.00	0.37500	297.00	2.56082E-02	2283.0
97	144.00	0.75000	361.00	2.54826E-02	1262.0
98	145.00	0.75000	342.00	8.15993E-03	2431.0
99	146.00	1.7500	846.00	4.41944E-03	2478.0
100	147.00	1.8750	694.00	7.29746E-02	1499.0
101	148.00	2.0000	280.00	8.27218E-02	1375.0
102	149.00	1.7500	4723.0	3.77762E-02	1350.0
103	151.00	1.00000E-03	4252.0	1.33333E-02	296.00
104	152.00	3.2500	4152.0	6.42857E-02	1441.0
105	153.00	3.2500	9026.0	-0.12169	212.00
106	154.00	8.2500	3117.0	0.14286	6.0000
107	160.00	1.0000	152.00	2.99860E-02	1391.0
108	161.00	1.3750	3435.0	5.42797E-03	2382.0
109	162.00	1.0000	2039.0	3.38066E-02	1429.0
110	163.00	1.1250	1470.0	2.21595E-02	4854.0
111	164.00	1.3750	3478.0	3.15126E-03	4745.0
112	165.00	0.87500	1391.0	1.09073E-02	1995.0
113	166.00	0.87500	413.00	1.51786E-02	4412.0
114	167.00	0.62500	875.00	2.15081E-02	3867.0
115	168.00	0.87500	1033.0	-0.51914	3254.0
116	169.00	0.75000	593.00	-2.14592E-03	467.00
117	171.00	1.2500	21092.	0.10127	355.00
118	181.00	0.37500	909.00	1.45103E-02	2445.0
119	182.00	1.2500	12601.	0.10549	407.00
120	183.00	0.50000	11355.	9.92366E-02	354.00
121	191.00	0.12500	2501.0	3.15118E-02	2428.0
122	193.00	3.3750	396.00	4.47827E-02	4330.0
123	194.00	0.25000	655.00	1.54394E-02	829.00
124	201.00	1.7500	136.00	3.93162E-02	5620.0
125	202.00	0.37500	170.00	2.50313E-02	1558.0
126	203.00	1.3750	10132.	0.50819	781.00
127	204.00	0.50000	74.000	6.52952E-02	1045.0
128	211.00	2.2500	84.000	2.51490E-02	5233.0
129	212.00	1.0000	122.00	1.12693E-02	3334.0
130	213.00	0.87500	589.00	1.09152E-02	1178.0
131	214.00	3.1250	15467.	2.09790E-02	140.00
132	215.00	1.0000	588.00	2.23464E-02	1575.0
133	216.00	1.0000	327.00	1.25232E-02	2129.0
134	217.00	1.0000	2185.0	9.76042E-02	1017.0
135	218.00	5.3750	12017.	3.95480E-02	170.00
136	221.00	1.7500	2171.0	1.63265E-03	1223.0
137	222.00	1.5000	1233.0	-2.93255E-03	342.00
138	223.00	1.6250	3533.0	9.62963E-02	122.00

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139   224.00       0.62500      1277.0       0.21038          289.00
140   225.00        2.2500      1389.0       1.63537E-02      1624.0
141   226.00        3.1250      953.00       5.08647E-02      933.00
142   227.00        1.2500      2691.0       5.48780E-02      465.00
143   228.00        1.8750      4697.0       9.09091E-02      10.000
144   231.00       0.87500     0.0           4.13943E-02      1320.0
145   232.00        1.5000      117.00       3.69541E-02      3440.0
146   233.00       0.75000      180.00       3.23102E-02      2396.0
147   234.00        1.2500      200.00       2.44039E-02      3478.0
148   235.00        2.7500      176.00       1.73469E-02      1926.0
149   236.00        2.8750      415.00       2.10347E-02      3444.0
150   237.00        3.3750      623.00       2.37838E-02      2709.0
151   238.00        4.6250      1119.0       3.16742E-02      1284.0
152   239.00        4.8750      2321.0       1.48423E-02      1062.0
153   241.00       0.87500      65.000       2.37203E-02      782.00
154   242.00       0.25000     0.0           2.95047E-02      921.00
155   243.00        1.1250     0.0           2.52294E-02      1275.0
156   244.00        3.2500      1364.0       1.88679E-03      2116.0
157   251.00        9.7500      11853.       0.10619          101.00
158   261.00        1.0000      5661.0       9.59902E-02      2232.0
159   291.00        1.6250      5528.0       0.11111          56.000
160   292.00        3.8750      12372.       0.10494          145.00
161   331.00        3.0000      727.00       2.04604E-02      1915.0
162   332.00        2.7500      636.00       1.18084E-02      2929.0
163   333.00        1.2500      25.000       2.91335E-02      3899.0
164   334.00       0.50000     0.0           2.63523E-02      702.00
165   335.00        1.3750      77.000       2.87908E-02      2530.0
166   341.00        6.0000      12177.       0.10294          305.00
167   351.00        2.0000      706.00       9.03010E-02      816.00
168   352.00        3.7500      3892.0       0.17097          834.00
169   353.00        1.3750      6264.0       0.10345          494.00
170   361.00       0.75000      907.00       4.15430E-02      4522.0
171   362.00        1.7500      5698.0       0.10409          1007.0
172   371.00       0.75000      235.00       1.38014E-02      3287.0
173   372.00        3.5000      5062.0       4.07450E-02      1648.0
174   373.00        1.7500      4343.0       0.10714          150.00
175   381.00        1.0000      10943.       0.10381          682.00
176   382.00        1.5000      1326.0       2.43684E-02      4364.0
177   383.00        2.7500      2383.0       9.06845E-02      2577.0
178   384.00        1.5000      1998.0      -6.25000E-02      612.00
179   391.00        3.7500      2117.0       8.69565E-02      42.000
180   392.00        1.8750      21871.       0.10217          580.00
181   393.00        1.2500      10123.       0.10036          2223.0
182   402.00        3.2500      11951.       0.10490          128.00
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OBS    DISTRICT     TOTLU      SEWER70     WATER70     URBAN70
  1     11.000     286.00      286.00      286.00      259.00
  2     12.000     301.00      301.00      301.00      287.00
  3     21.000     249.00      249.00      249.00      201.00
  4     22.000     561.00      561.00      561.00      404.00
  5     23.000     524.00      524.00      524.00      419.00
  6     24.000     942.00      942.00      942.00      814.00
  7     25.000     919.00      919.00      919.00      728.00
  8     26.000     722.00      722.00      722.00      668.00
  9     27.000     757.00      757.00      757.00      659.00
 10     28.000     324.00      324.00      324.00      285.00
 11     29.000     894.00      894.00      894.00      553.00
 12     30.000     233.00      233.00      233.00      210.00
 13     31.000     1235.0      1235.0      1235.0      1040.0
 14     32.000     1748.0      1748.0      1748.0      1541.0
 15     33.000     522.00      522.00      522.00      457.00
 16     34.000     341.00      341.00      341.00      295.00
 17     35.000     1206.0      1206.0      1206.0      1117.0
 18     36.000     382.00      382.00      382.00      338.00
 19     37.000     513.00      513.00      513.00      340.00
 20     38.000     497.00      497.00      497.00      156.00
 21     39.000     365.00      365.00      365.00      324.00
 22     41.000     2254.0      2254.0      2140.2      1570.0
 23     42.000     4713.0      4613.6      4713.0      469.00
 24     43.000     3320.0      632.79      2548.8      548.00
 25     44.000     1000.0      1000.0      1000.0      963.00
 26     45.000     972.00      972.00      972.00      887.00
 27     51.000     653.00      653.00      653.00      569.00
 28     52.000     646.00      646.00      646.00      602.00
 29     53.000     626.00      626.00      626.00      585.00
 30     54.000     1929.0      1929.0      1929.0      184.00
 31     55.000     1102.0      1102.0      1102.0      896.00
 32     56.000     1519.0      1519.0      1519.0      1071.0
 33     57.000     1785.0      1785.0      1430.5      622.00
 34     58.000     1681.0      1681.0      1681.0      322.00
 35     61.000     204.00      204.00      204.00      179.00
 36     62.000     444.00      444.00      444.00      405.00
 37     63.000     350.00      350.00      350.00      213.00
 38     64.000     642.00      642.00      642.00      597.00
 39     65.000     530.00      530.00      530.00      480.00
 40     66.000     429.00      429.00      429.00      296.00
 41     67.000     564.00      564.00      564.00      527.00
 42     71.000     1299.0      1299.0      1299.0      1086.0
 43     72.000     650.00      650.00      650.00      507.00
 44     73.000     1042.0      1042.0      1042.0      978.00
 45     74.000     2013.0      2013.0      1909.3      1147.0
 46     75.000     1639.0      1639.0      1516.1      702.00
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47	76.000	325.00	248.20	325.00	233.00
48	80.000	630.00	630.00	630.00	448.00
49	81.000	568.00	568.00	568.00	554.00
50	82.000	954.00	954.00	954.00	573.00
51	83.000	724.00	724.00	724.00	603.00
52	84.000	527.00	527.00	527.00	424.00
53	85.000	519.00	519.00	519.00	494.00
54	86.000	717.00	717.00	717.00	479.00
55	87.000	461.00	461.00	461.00	392.00
56	88.000	907.00	907.00	907.00	801.00
57	89.000	740.00	740.00	740.00	656.00
58	91.000	982.00	982.00	982.00	848.00
59	92.000	949.00	949.00	949.00	724.00
60	93.000	398.00	398.00	398.00	292.00
61	94.000	564.00	564.00	564.00	486.00
62	95.000	970.00	970.00	970.00	808.00
63	96.000	998.00	998.00	998.00	694.00
64	97.000	958.00	958.00	958.00	819.00
65	98.000	943.00	719.13	943.00	203.00
66	100.00	978.00	978.00	978.00	892.00
67	101.00	676.00	676.00	676.00	595.00
68	102.00	413.00	413.00	413.00	341.00
69	103.00	1259.0	1259.0	1259.0	1128.0
70	104.00	639.00	639.00	639.00	502.00
71	105.00	471.00	471.00	471.00	426.00
72	106.00	510.00	510.00	510.00	465.00
73	107.00	624.00	624.00	624.00	487.00
74	108.00	957.00	957.00	957.00	894.00
75	109.00	1009.0	1009.0	1009.0	779.00
76	111.00	38052.	9832.6	22755.	2239.0
77	112.00	3907.0	2159.4	3907.0	716.00
78	113.00	9946.0	4560.2	9155.3	1508.0
79	114.00	3629.0	3374.2	3390.2	1354.0
80	121.00	3839.0	2489.2	3839.0	1381.0
81	122.00	3419.0	3379.7	3419.0	1564.0
82	123.00	3277.0	3277.0	3277.0	1569.0
83	130.00	990.00	990.00	990.00	693.00
84	131.00	2512.0	2512.0	2512.0	1130.0
85	132.00	1470.0	1470.0	1470.0	692.00
86	133.00	997.00	997.00	997.00	757.00
87	134.00	984.00	984.00	984.00	822.00
88	135.00	1007.0	1007.0	1007.0	734.00
89	136.00	987.00	987.00	987.00	823.00
90	137.00	1498.0	1498.0	1498.0	791.00
91	138.00	1798.0	1798.0	1564.4	940.00
92	139.00	1000.0	1000.0	1000.0	722.00

93	140.00	965.00	965.00	965.00	229.00
94	141.00	8544.0	5988.5	3149.3	1498.0
95	142.00	1632.0	1632.0	1632.0	1254.0
96	143.00	983.00	983.00	983.00	657.00
97	144.00	973.00	973.00	973.00	563.00
98	145.00	970.00	970.00	970.00	558.00
99	146.00	1648.0	1648.0	1648.0	733.00
100	147.00	1582.0	1582.0	1582.0	701.00
101	148.00	1016.0	991.11	875.49	642.00
102	149.00	7086.0	3100.8	2737.3	782.00
103	151.00	5932.0	1157.3	1308.0	699.00
104	152.00	5221.0	3952.8	4682.7	969.00
105	153.00	9883.0	685.88	782.73	493.00
106	154.00	11137.	295.13	6462.8	4025.0
107	160.00	1314.0	1314.0	1314.0	668.00
108	161.00	4808.0	2903.6	4566.2	933.00
109	162.00	2545.0	976.01	2492.6	371.00
110	163.00	3310.0	2565.6	2452.4	1619.0
111	164.00	7922.0	4625.7	5997.0	2141.0
112	165.00	3101.0	2741.6	3101.0	1371.0
113	166.00	1990.0	1990.0	1990.0	1458.0
114	167.00	2658.0	2658.0	2658.0	1443.0
115	168.00	3374.0	3374.0	3374.0	1786.0
116	169.00	2218.0	2218.0	2011.1	1010.0
117	171.00	25022.	2632.3	3840.9	657.00
118	181.00	2532.0	2532.0	2125.4	1140.0
119	182.00	13897.	1941.4	2527.9	584.00
120	183.00	13248.	400.09	13248.	915.00
121	191.00	4823.0	3684.3	1535.6	1611.0
122	193.00	3154.0	3154.0	281.65	2247.0
123	194.00	2254.0	2254.0	545.02	1181.0
124	201.00	1250.0	1250.0	1250.0	1053.0
125	202.00	790.00	790.00	790.00	398.00
126	203.00	12611.	1481.8	1571.3	1228.0
127	204.00	634.00	634.00	634.00	128.00
128	211.00	918.00	918.00	918.00	781.00
129	212.00	1051.0	1051.0	1051.0	847.00
130	213.00	1191.0	1191.0	1171.6	399.00
131	214.00	24101.	5032.3	2190.8	613.00
132	215.00	1384.0	1384.0	1384.0	541.00
133	216.00	1278.0	1278.0	1278.0	921.00
134	217.00	3247.0	2400.8	3247.0	780.00
135	218.00	26104.	0.0	4784.9	455.00
136	221.00	4290.0	1243.2	4290.0	1707.0
137	222.00	3404.0	1573.7	2396.1	791.00
138	223.00	4485.0	2679.3	1836.6	781.00

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139   224.00        2064.0        2011.4        2064.0        680.00
140   225.00        2572.0        2400.2        2572.0        711.00
141   226.00        2619.0        2605.9        2540.4        1412.0
142   227.00        3246.0        3192.8        1841.8        450.00
143   228.00        5159.0        1354.2        266.20        156.00
144   231.00        577.00        577.00        577.00        550.00
145   232.00        860.00        860.00        860.00        678.00
146   233.00        944.00        944.00        944.00        637.00
147   234.00        1562.0        1562.0        1562.0        1288.0
148   235.00        944.00        944.00        944.00        714.00
149   236.00        1465.0        1465.0        1465.0        904.00
150   237.00        2023.0        2023.0        2023.0        1125.0
151   238.00        1984.0        1963.6        1984.0        744.00
152   239.00        3239.0        3100.0        3239.0        714.00
153   241.00        729.00        729.00        729.00        555.00
154   242.00        1180.0        1180.0        1180.0        567.00
155   243.00        1080.0        1080.0        1080.0        605.00
156   244.00        3876.0        3876.0        3876.0        1313.0
157   251.00        15680.        958.05        5099.1        839.00
158   261.00        9404.0        2484.5        3999.5        1662.0
159   291.00        6411.0        377.61        0.0           198.00
160   292.00        14432.        626.35         141.43       421.00
161   331.00        1764.0        196.69         1460.1       432.00
162   332.00        1908.0        1439.0         1572.2       1123.0
163   333.00        941.00        941.00         941.00       811.00
164   334.00        385.00        385.00         385.00       57.000
165   335.00        1392.0        630.99         1359.1       410.00
166   341.00        15966.        2265.6         9943.6       756.00
167   351.00        1691.0        1691.0         1691.0       667.00
168   352.00        7328.0        6711.0         5532.6       1348.0
169   353.00        10610.        2781.9         4793.6       641.00
170   361.00        2679.0        2679.0         1961.3       1074.0
171   362.00        8612.0        2151.3         3730.7       1520.0
172   371.00        4777.0        2076.6         3131.3       1182.0
173   372.00        14045.        1127.8         5573.1       928.00
174   373.00        9837.0        842.05         23.609       571.00
175   381.00        12189.      0.0              3804.2       495.00
176   382.00        2953.0        1737.5         2953.0       1394.0
177   383.00        3316.0        2268.8         3287.5       851.00
178   384.00        2518.0        2283.1         2309.5       381.00
179   391.00        2174.0        142.83         757.64       31.000
180   392.00        23808.        1121.4         4045.0       708.00
181   393.00        12980.        7564.7         6136.9       1169.0
182   402.00        12726.      0.0              735.56       226.00
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